THE SURGICAL TREATMENT OF FACIAL INJURIES

by

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TO THE MEMORY OF

HARRY H SHAPIRO D M D

Anatomist and dental surgeon,
poet and composer of music.

His wish was that this book
be dedicated to the facially disfigured
and to the relief of their suffering

PREFACE

As in the first edition our purpose in this book is to stress our viewpoint with respect to the surgical treatment of facial injuries and to cover this one subject thoroughly We draw from vast experience in World Wars I and II and in civilian practice As in the previous edition we have limited the techniques described to those with which we have had actual personal ex perience We do not wish to minimize the importance of other techniques not included in this volume. We owe much of our knowledge to those who have preceded us and we gratefully acknowledge our debt to them and to our contemporaries in this field

This second edition contains six new chapters Introduction to Fractures of the Facial Bones Fractures of the Fronto-Ethmoidal Region and Traumatic Cerebrospinal Rhinorrhea Facial Injuries in Children Roentgen Exami nation of the Facial Bones The Transplantation of Tissues and Scars of the Face Most of the other chapters have been considerably expanded

Over 400 new illustrations have been added. Most of the new drawings are by Miss Daisy Stilwell, whose interest in plastic surgery and broad experience in the field make her high quality drawings invaluable for teach ing Miss Patricia Blake, Mr Leonard D Dank and Mr Eric J Derum also contributed some excellent drawings

To supply a surgical background for the student and practitioner the first three chapters deal with a brief survey of the evolution of the human face and some aspects of anatomy the healing of wounds, and general principles of operating technique. These subjects are followed by chapters dealing with fractures of the bones of the face and jaws. Later chapters of the text are devoted to general principles of reconstructive surgery Deformities of the upper portion of the face eyelids, orbital and zygomatic regions, nose and soft tissues and bones of the lower portion of the face are discussed Included also are chapters dealing with reconstructive techniques of the oral cavity and pharynx, temporomandibular ankylosis, facial paralysis deformities of the external ear and burns of the face. No text dealing with reconstructive surgery of the maxillofacial area is complete without due consideration of the roles of the jaws and the dentition We have attempted to evaluate the prosthetic and surgical aspects of facial reconstruction and to define their relative importance in a chapter on maxillofacial prosthetics.

There is no person more severely handicapped than the patient with severe facial disfigurement. Since the face is the center of attention wherever social interaction occurs, the region where the sense of self is generally lo- cated the dominant part of the body image and the most revealing area of personality traits, those who have gross facial deformity undergo countless indignities and social deprivations

In this new text an attempt has been made to integrate the basic biologic principles governing tissue transplantation with the principles of surgical treatment a cursory review of tissue transplantation is included in the chapter so designated.

The authors have had an unusually close collaboration over the past twenty years. The junior author feels very privileged to have benefited from the affectionate intimacy of his teacher one of the pioneers of plastic surgery in our time, whose sum of experience totals a half century

ACKNOWLEDGMENTS

We have dedicated this book to the late Dr Harry H Shapiro our friend, who edited the text and made many useful suggestions concerning the contents. His interest in the problems of the victims of facial injuries culminated in his devoting a major portion of his time to the Society for the Rehabilitation of the Facially Disfigured, of which he became executive director in 1951 His knowledge, innumerable talents and unfailing sense of humor will be missed.

Our deep gratitude goes to a number of our colleagues in associated fields who consented to collaborate with us on various sections of the book. Dr Edgar A. Kahn Professor of Neurosurgery and Dr Richard C. Schneider of the Department of Surgery Section of Neurosurgery University of Michigan Medical School, helped prepare Chapter 10 dealing with fractures of the frontoethmoidal region Dr Judah Zizmor *Roentgenologist of the* Manhattan Eye Ear and Throat Hospital contributed Chapter 13 on the roentgen examination of the facial bones. The assistance of Dr Blair O Rogers and of Dr Felix T Rapaport is gratefully acknowledged in the preparation of Chapter 15 a review of the principles of tissue transplantation. Dr Byron Smith Surgeon Director in charge of ophthalmic plastic surgery at the Manhattan Eye, Ear and Throat Hospital collaborated in the preparation of Chapter 21 dealing with deformities of the eyelids and orbital region. In Chapter 27 on facial paralysis, Dr Joseph Goodgold of the Institute of Rehabilitation and Physical Medicine, New York University Bellevue Medical Center contributed the section on electrodiagnosis. Dr Richard J Bellucci, Surgeon Director in charge of the Hearing and Speech *Clinic of the Manhattan Eye Ear and Throat Hospital contributed the* section on the intratemporal repair of the facial nerve. Dr James H Maxwell Department of Otolaryngology University of Michigan Medical School kindly allowed us to include one of his cases of repair of the branches of the facial nerve.

The junior author wishes to express his deep appreciation to Dr John H Mulholland George David Stewart Professor of Surgery New York University College of Medicine, for his friendly advice and guidance over the years and to his long time associate Dr Ross M. Campbell many of the patients shown have been treated in collaboration with him To Mr Thomas D Arcy Brophy President, and the Trustees of the Society for the Rehabilitation of the Facially Disfigured and to Mr G Lauder Greenway Dr Thomas Parran and the Trustees of the Avalon Foundation go our thanks for making possible much of the work necessary to complete this book.

The checking and listing of the bibliography a seemingly unsurmountable task, were accomplished by Miss Pauline Porowski, R.N in addition to her other duties and responsibilities. Miss Margaret L. Newton did much of the typing of the manuscript, assisted by Miss Margaret Gibbons and Miss Virginia Angelo

The authors also wish to thank the Publisher for the patience and coöperation necessary to produce a technical book, particularly a succeeding edition.

V H. K.
J M C.

CONTENTS

1

THE FACE

The face of man is formed of soft expressive tissues draped upon an underlying framework of bony structures. Endowed with an inherent ability to convey emotions through the interplay of flexible facial structures and with such highly specialized organs as those of vision, audition and speech, humans possess the precious art of communication with their fellows.

In civilized man the face alone remains unclothed and exposed. An injury resulting in distortion of the features thus sets the unfortunate individual apart in a highly organized society where a premium is placed upon beauty and facial symmetry. Because disfigurement of the face becomes a serious social handicap, the surgical treatment of facial injuries is of special significance as it serves to restore the inner feelings of happiness and well being in addition to the outer appearance and function.

EVOLUTIONARY CONSIDERATIONS

The structures of the human face owe their origin to primordia of the head and neck which begin to be outlined as early as the third and fourth weeks of embryonic life. A remarkable series of intra-uterine transformations then ensue which repeat in great part the evolutionary history of mammalian development.

Because an awareness of these processes is of assistance in understanding anomalous as well as normal development, the authors have chosen to begin this text with a brief consideration of these interesting and pertinent ancestral relationships.

The Jaws

Analysis of the component parts of the face of invertebrate or vertebrate forms suggests that the mouth is the central and most essential feature of the face. The mouth in its simplest form, as seen in the obelia, is merely a circular opening in a cylindrical bag. In the crustaceans, insects and other arthropods, accessory mouth parts are elaborated out of locomotor appendages. In the vertebrates the jaw parts consist of an entirely different set of organs, the gill arches. The transformation of gill arches into jaws is seen in various stages among the vertebrates. The primary jaws, the result of this transformation, become covered and replaced by secondary jaws in the higher forms. The gill pouches of fishes and embryos of higher vertebrates are supported by cartilaginous bars, the visceral arches. The mouth pouches of sharks and of embryo vertebrates are supported by similar cartilages. A modified first visceral cartilage forms the cartilages of the upper and lower jaws in the shark, (Fig. 1A), the cartilage of the lower jaw, Meckel's cartilage, articulates with that of the upper jaw. The sucking mouth of lower animals is thus replaced by the mouth with teeth. The upper jaw does not fuse with the cranium but remains an independent component of the skull. The hyomandibular cartilage, a portion of the second visceral arch, serves as a suspensory apparatus for the lower jaw, connecting the jaw to the brain trough. In amphibians and in reptiles the upper jaw is firmly attached

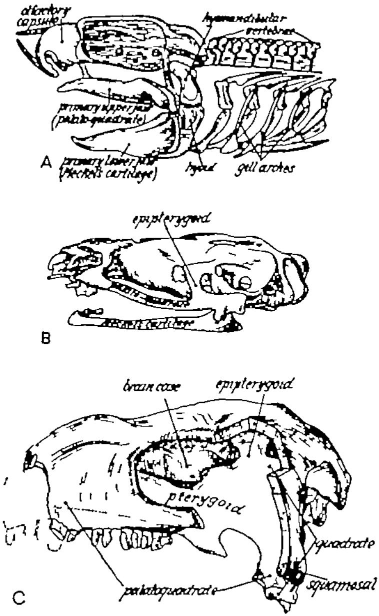

FIG 1 Methods of attachment of the primary upper jaw to the under side of the skull

A. Hyostylic attachment (by means of the hyomandibular cartilage) characteristic of shark.

B. Autostylic attachment (by means of an epipterygoid process from the primary upper jaw) Cartilaginous braincase and primary upper jaw of fetal salamander

C. Skull of primitive fossil reptile (Diadectes) from the Permo-Carboniferous of Texas. The bony mask covering the temporal region is cut through and a part of it removed to show the primary upper jaw (comprising the palatine, pterygoid, epipterygoid, and quadrate bones) and their relations to the braincase From William K. Gregory *Our Face from Fish to Man*, G P Putnam's Sons, 1929

to the skull (Fig 1*B* *C* Fig 2) The hyomandibular cartilage slips into the tympanic cavity to form the stapes. The remaining visceral arches are reduced and associated with the larynx. The primary jaws are destined to be supplanted by secondary jaws.

Large bony plates and scales appeared in the skin of ancestral vertebrates. These dermal scales sank into the deep layers of the skin in later forms and became ensheathed and covered largely supplanting the primary jaws.

In sharks, the secondary jaws are represented by the skin which covers the primary jaws. The primary jaws in the higher fishes and in early amphibians are ensheathed by bony tooth bearing plates covered with ganoine a porcelain like substance the skele-

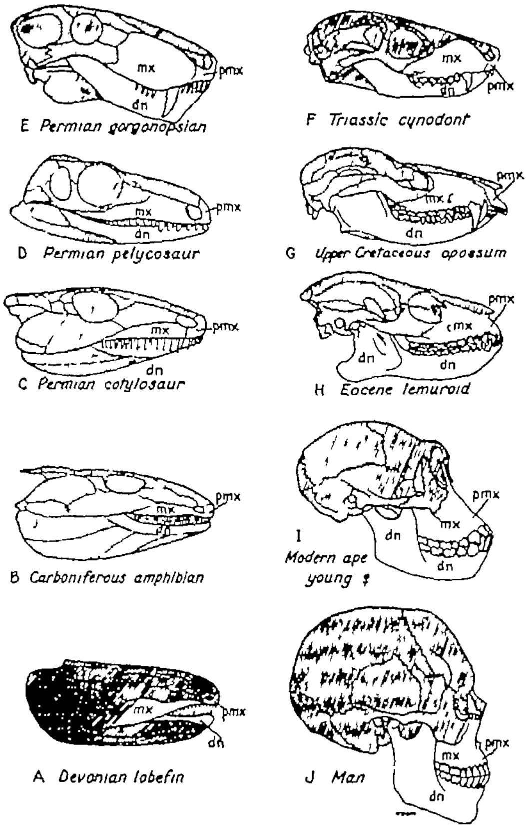

FIG 2 Evolution of the human jaw-bones (Gregory) Abbreviations pmx, *premaxilla* mx, *maxilla* dn *dentary*

The maxillary bone in its earlier form, is a slender vertically shallow element. By the time of the early mammal-like reptiles it has extended dorsally and gained contact with the nasals (D E) In the mammals it extends still further reaching the frontal bone and separating the lacrimal from the zygoma (G H I J) In anthropoids and man the premaxillae unite with the maxillae (I J) The dentary is at first confined to the anterior half of the mandible (A) In the higher mammal like reptiles it becomes dominant (E) and in the earliest mammals the ascending ramus of the dentary gains a new contact with the squamosal the temporo-mandibular joint (G H)

ton of the human face has been traced back to these origins. In higher mammal like reptiles and in mammals three of these tooth bearing plates are found throughout the scale of the vertebrates. These are the premaxilla and maxilla paired bones of the upper jaw and the dentary paired bone of the lower jaw (Fig 2)

Thus it appears that the jaws are formed by a number of distinct bony plates, some of which disappear in the higher vertebrates. The premaxilla and dentary persist in man while the pterygoids and quadrates of the upper jaw and the elements behind the dentary of the lower jaw are progressively diminished

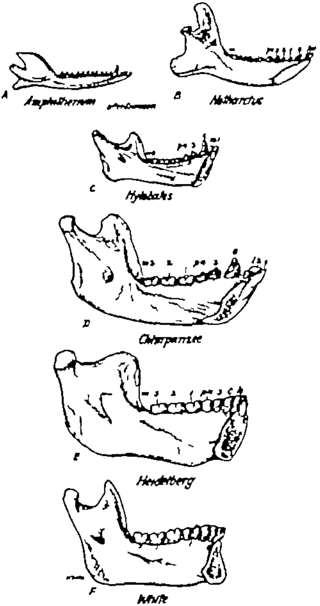

FIG. 3. Evolution of the mandible in primates (Gregory) The evolution of the mandible in primates (B to E) involves the shortening of the horizontal portion or body of the mandible with a reduction in the dental formula. Later human stages were characterized by the refinement of the jaw and the outgrowth of the chin (F)

The dentary bone in the higher vertebrates leading to the mammals increases in size until it crowds out the other elements of the lower jaw This increase of the dentary bone causes it to press against the jaw muscles in which its upper end is embedded. The pressure gives rise to a bursa formed by a slip of the external pterygoid muscle which passes between the lower jaw and its socket in the squamosal bone. The socket formed by the pressure of the dentary bone of the lower jaw against the squamosal characterizes the mammalian temporomandibular joint (Fig 2G J) as contrasted with the reptilian joint between the quadrate bone of the upper jaw and the articular bone of the lower jaw

The maxilla increases in height, joining with the nasal bones in the early mammal like reptiles (Fig 2E) The frontal process of the maxilla usually meets the frontal bone in most mammals without disrupting the primitive contact between the lacrimal and zygomatic bones the maxillary process merely overlaps the facial extension of the lacrimal. The separation of the zygoma from the lacrimal bone is probably associated with outward displacement of the zygoma widening and shortening of the jaws, pull of the masseter muscle, and widening of the brain The upper jaw becomes shortened antero-posteriorly and increased vertically thus greatly modifying the shape of the face in anthropoids and in man (Fig 2I J) In primates, the shape of the face is further influenced by the subsequent evolution of the mandible involving chiefly the shortening of the body of the jaw and a reduction in the dental formula (Fig 3) In anthropoids and in man the dentaries of each side finally fuse to form the mandible sole survivor of eighteen bones in the ancestral lobe finned fish The outgrowth of a chin and the re-

finement of the jaw are characteristic of man (Fig 3E, F)

The Mouth

Cheeks and Lips

The mouth in lower forms is large, somewhat funnel-shaped and lacks lateral walls. The oral cavity of the herbivora is bounded by cheeks which prevent the escape of food during mastication Cheeks are well-developed in monkeys, higher apes and man Mobile lips, variously formed are seen in all mammals, perhaps due to the need for obtaining nourishment by suckling during infancy (Negus, 1938)

The Tongue

The size and shape of the tongue varies considerably in animals. The chameleon anteater and giraffe use it for grasping food The crocodilia bolt their food with the aid of a flat, mobile tongue. The tongue of a carnivorous animal is well-formed and mobile and is exceptionally well-developed in the herbivora The relatively large size of the tongue in modern man may be traced to the large oral cavity of earlier man its dimensions and mobility are of assistance in speech.

The Nose

The early development of the face is linked to that of the mouth and jaws. The growth of an independent olfactory and air breathing apparatus is a later development.

In the olfactory apparatus of the shark the nose communicates with the mouth cavity through an external oronasal groove. This groove is closed anteriorly in lung fishes. A tube, thus formed extends from the nose to the mouth cavity and the nasopharyngeal duct and the functional association of the olfactory sense with the inspired air is thus established The development of an independent air-breathing apparatus led to further progressive evolutionary changes the air inspired into the olfactory chamber of amphibians, is enabled to pass through a pair of tubes opening into the anterior portion of the roof of the mouth

The choanae open into a chamber lying above the level of the tooth bearing bones of the upper jaw in early mammal like reptiles. A secondary palate is formed in higher mammal like reptiles by horizontal out growths of bony plates from the palatine and maxillary bones that form a shelf below the choanae The bony palate in mammals is prolonged posteriorly and a muscular sphincter the soft palate separates the oral and nasal cavities.

The elongated olfactory capsules of mammal like reptiles are squeezed together their median walls form a bony partition the mesethmoid which bears scroll like out growths that offer a wide surface for the testing of odors. The sense of smell is highly developed in mammals as evidenced by the large scroll like turbinates in the nasal fossae The cartilaginous nose is supported by a median cartilage which rests in a groove in the vomer and is continuous posteriorly with the mesethmoid bone.

The first primitive primates small and long-snouted much like tree shrews of today were evolved in the Eosene some 60 million years ago They were tree dwellers the subsequent development of the higher primate face seems to be largely dependent upon this mode of life (Hooton, 1946) The primitive ground-dwelling animal must be provided with a long, pointed snout tipped by the nose which is the *principle organ of* touch and the sole organ of smell since he cannot see above the long grass he is forced as Wood Jones has said, to nose his way through life, depending for the detection of food largely on the tactile and olfactory functions of his soft, damp muzzle. Beneath the elongated snout is the mouth, provided with teeth and dental arches corresponding to the elongated shape of the snout. When the ancestors of these primitive primates took to the trees, arboreal life resulted in considerable diminution of the function of the face. Tree life placed a premium upon the sense of vision as contrasted with the

olfactory sense upon which the small weak ground-dweller depended for his existence. Agility and motor co-ordination were required to permit an animal to move about the trees without falling; keen eyesight supplanted the sense of smell as the principle *survival faculty. A change in the shape of* the face occurred characterized by the recession of the muzzle and a lessening of the transverse dimension of the nasal cavity. The recession of the nasal cavities permitted the forward progression of the orbits and the shortening of the jaws. With the shortening of the snout in the higher primates, a true external nose emerges between the nostrils. The nostrils are widely separated in the New World or platyrrhine monkeys, and open outwardly on each side of the broad tip and columella of the nose. In the Old World or catarrhine monkeys, and in apes and man, the nostrils are drawn downward and inward toward the mid line (Fig. 4).

The Zygomatic Arch and the Orbits

The evolution of the zygomatic arch is observed in the extinct mammal like reptiles of South Africa. The upper surface of the skull in the earliest fossil fishes, amphibians and reptiles is covered by a bony mask with openings for nostrils, eyes, and ears; the temporal jaw muscles lie beneath this mask. The bony shell which covers the temporal muscles is absorbed in the early mammal like reptiles, leaving a round fossa behind the orbit and lateral to the side wall of the braincase (Fig. *5D*, *E*).

The skull approaches the mammalian type in the development of a temporal fossa and a cheek arch (Fig. *5D*, *E*, *F*). The temporal muscles overflow on top and the roofing bones sink beneath the surface. Thus, in primitive mammals like the opossum the jaw muscles cover the parietal and a portion of the frontal bone, whereas in earlier stages they lie beneath these bones. This may be seen by comparing the skull of the opossum (Fig. *5G*) with that of a mammal like reptile (Fig. *5F*). Man inherits only two of the five original bones which surrounded the orbit; these are the lacrimal and the zygomatic bones. The maxilla separating these two bones increases the width of the face (Fig. 2). The decrease in the *number of circumorbital bones is* accompanied by a forward progression of the orbits from their more lateral position, thereby permitting binocular vision, and by a progressive diminution in the number of bones in the skull, a phenomenon referred to as "Williston's law" (Fig. 5).

The face, seat of the principal sense organs, began in the early Eosene primates to undergo changes consisting of a progressive development of all the senses except that of smell which was destined to partial retrogression. A greater dependence upon vision tended to enlarge the visual areas of the brain at the expense of the primitive olfactory areas. The brain expanded laterally and posteriorly in accordance with the location of the visual centers in the occipital lobes of the cerebrum and with the concomitant shrinking back of the muzzle. The head tended to become balanced upon the erect spine, thus facilitating the upright position without the muscular effort required by the vast overbalancing of a protrusive muzzle. The increase in the size of the brain in man achieved the vertical development of the face by increasing the size of the frontal region. Sagittal sections of the skull of the gorilla and man reveal that the frontal region of the brain in man has grown forward above the olfactory chamber (Fig. 6).

Fossils discovered in Africa and in Asia have many characteristics resembling those of the anthropoid apes. The resemblance becomes *closer in the Australopithecus of* South Africa which possessed an erect posture, a characteristic considered specific in man. Added knowledge of the links between man and the anthropoids followed the discovery of Pithecanthropus and Sinanthropus.

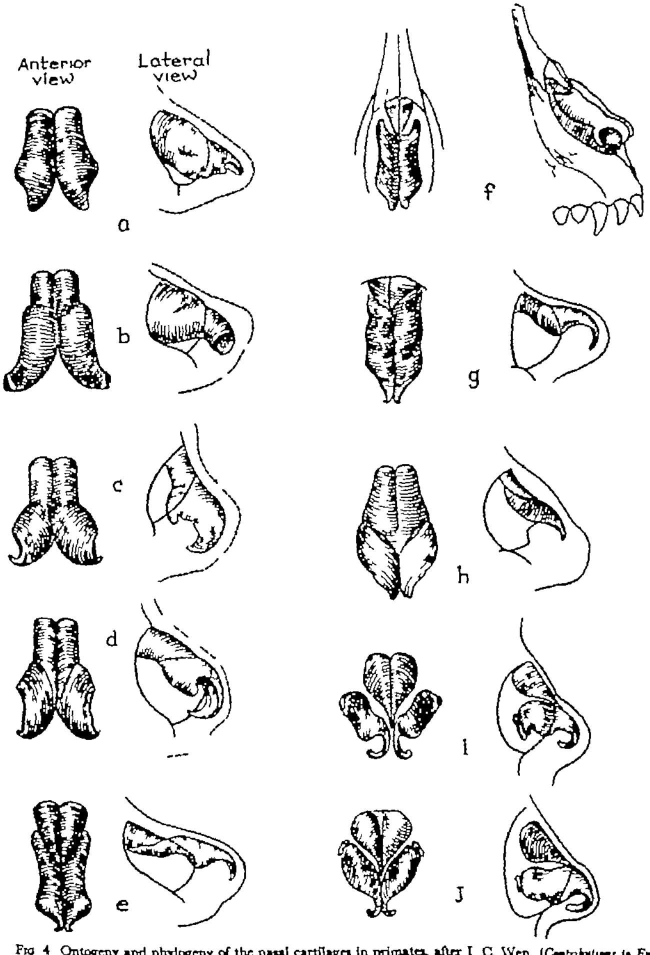

Fig 4 Ontogeny and phylogeny of the nasal cartilages in primates, after I C. Wen (*Contributions to Embryology* Carnegie Institution, Washington 414 109 1921)

A. Prosimian *Lemur variegatus* B Prosimian *Tarsius saltator* C. Platyrrhine *Callithrix jacchus* D Platyrrhine *Alouata palliata* E. Catarrhine *Erythrocebus patas* F Catarrhine *Pygathrix catellus* G Anthropoid ape *Hylobates pileatus* H Anthropoid ape *Pongo pygmaeus* I Man negro J Man white.

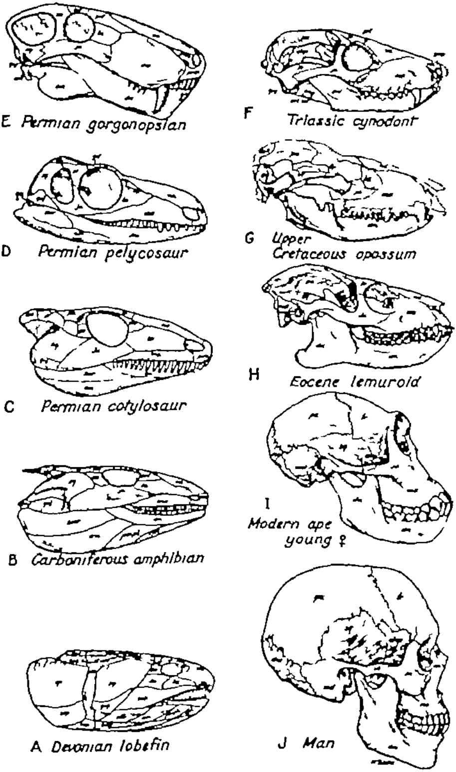

Fig 5 Evolution of the bones of the skull

Figures A to J give excellent examples of "Williston's Law" the progressive diminution in number of the elements of the skull in passing from fish to man (Gregory)

Origin of the Facial Musculature

In the most primitive living mammals, the bony mask of the face was replaced by a pliable skin after the dermal bones began to sink beneath the surface (Fig 7)

The development of the facial muscles, which gave mobility to the face and reached a high development in primates resulted in a characteristic mammalian feature This musculature appears to owe its origin to a thin wide band of muscle in reptiles, the primitive sphincter colli activated by a branch of the seventh cranial nerve. This muscle has grown forward along the sides and top of the face in mammals. The matrix muscle layers, platysma and sphincter colli profundus spread over the head and face from the neck, and gave rise to the various facial muscles (Huber 1931 Fig 8) Whereas in all vertebrates below the mammals the superficial musculature was restricted to the region of the neck in mammals it spread over the head onto the face where it achieved connections with the freely movable skin (Fig 9) Certain portions of the musculature became connected with the external ear some were grouped around the eye others became attached to the snout, while still others were arranged around the mouth Thus distinct facial muscles arose from the muscular matrix of the neck and the facial nerve which innervated this matrix supplied the facial musculature

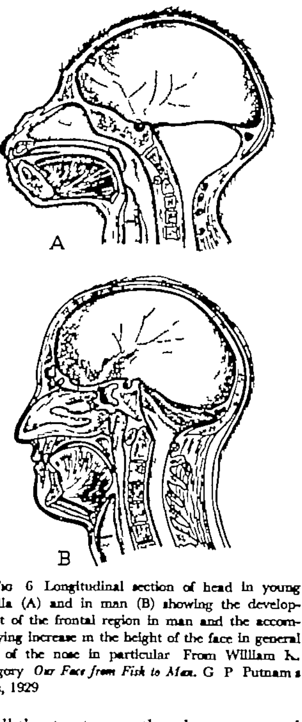

Fig 6 Longitudinal section of head in young gorilla (A) and in man (B) showing the development of the frontal region in man and the accompanying increase in the height of the face in general and of the nose in particular From William K. Gregory *Our Face from Fish to Man*. G P Putnam's Sons, 1929

ANATOMICAL CONSIDERATIONS

The anatomical limits of the face have been variously defined. Some anatomists have described the face as that portion of the head consisting essentially of the area which comprises the jaws, while others have also included the frontal area Leonardo da Vinci divided the ideal face into thirds from the hairline to the chin. It is interesting to note that Malgaigne (1838) extended the area still further delimiting the facial area as illustrated in Figure 10

All the structures within the area covered by the muscles of facial expression are included in this description because of surgical considerations. The loss of the scalp for example, may involve structures associated with the face burn contractures of the neck may also result in facial deformities.

Bony Structure of the Face

The bones which form the framework of the face are divided into those of a lower

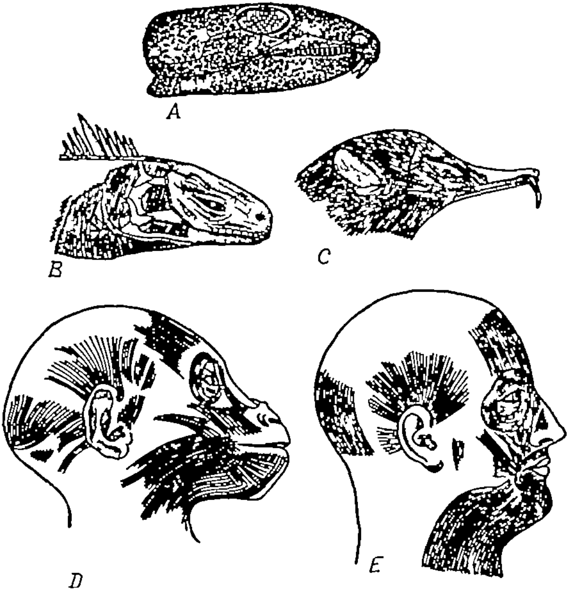

Fig 7 Origin of the facial muscles of man

A. Primitive reptile (Labidosaurus) with continuous bony mask covering skull The mask was covered with thick skin without muscles, as in the alligator

B. Modern reptile (Sphenodon) with an open or fenestrated skull covered with thick, nonmuscular skin The seventh nerve (heavy black line) is seen beneath the sphincter colli muscle, a broad band around the throat.

C. Primitive mammal (Echidna) in which the sphincter colli system has grown forward over the face.

D Gorilla.

E. Man. From William K. Gregory *Our Face from Fish to Man* G P Putnam's Sons, 1929

portion the face proper or maxillofacial area, and those of the cranial area The maxillofacial area may be delineated in the shape of a prism (Fig 11) situated in front of the large arteries and the cranial nerves, the base of the skull and the spinal column. The architectural design is admirably adapted for the protection of these structures. The maxillofacial prism is formed by columns of compact bone and thin lamellar bone and is attached to the skull by strong abutments, two anteromedial extending on each side from the canine fossa to the frontal bone two anterolateral the zygomatic arches and two posteromedial the pterygosphenoid abutments (Fig 12) The frontal

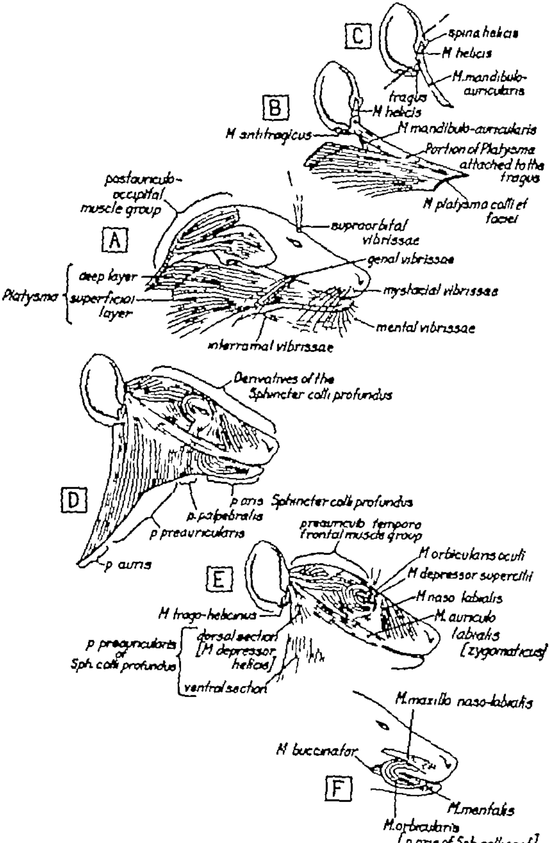

FIG 8. Scheme of the Primitive Primate Ground Plan of the Facial Musculature (based on investigations of Lemuroidea, Tarsius, and primitive platyrrhine monkeys) (Huber) The superficial facial musculature is a genitically uniform muscle field innervated exclusively by the facial nerve. From the neck region the matrix muscle layers, platysma and sphincter colli profundus have spread over the head into the face where they have given rise to the various muscle complexes and individual facial muscles.

A–C show the platysma and its derivatives.

D–F the sphincter colli profundus and its derivatives.

A and E moreover show the facial tactile vibrissae arranged according to the primitive mammalian ground plan.

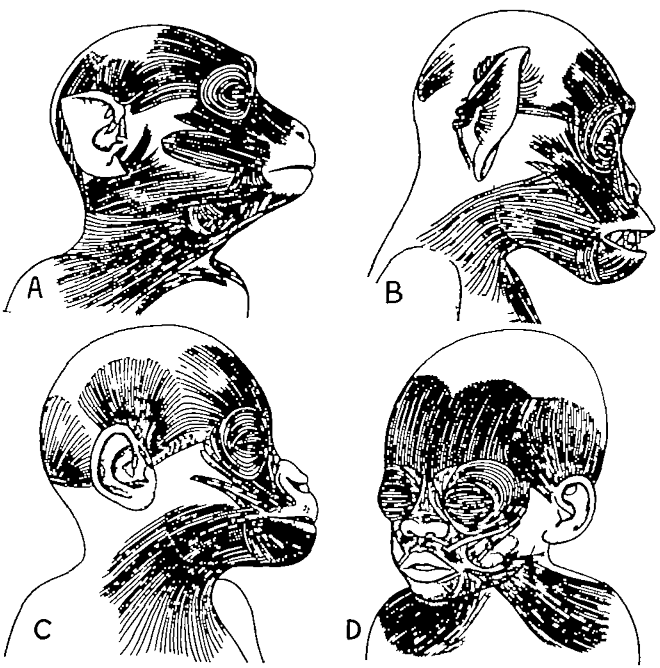

Fig 9 Evolution of the facial musculature

A. Macaque, a representative of the lower catarrhines (Huber) The facial musculature of the macaque has evolved not quite to the level which the higher platyrrhines have reached this especially in regard to the platysma and the postauriculo-occipital muscle group. The buccal pouch has led to considerable modifications in the platysma through which it has herniated Note the buccinator muscle which forms the muscular lining of the pouch. As regards facial expression in the macaque and the other representatives of the lower catarrhines this is brought forth through crude grimace-like group actions of facial muscles. The range of individual features of facial expression in the lower catarrhines is comparatively small.

Both the chimpanzee (B) and the gorilla (C) share with man (D) not only a common ground plan of the facial musculature but also similarly directed evolutionary trends. Note that in all three the nuchal portion of the platysma has disappeared, thus leaving the auriculo-occipital musculature isolated on the occiput Note the formation of the zygomatic muscle in the gorilla (B) Summarily it may be stated that man (D) far surpasses both chimpanzee and gorilla in the structural differentiation and especially in the functional perfection of the musculature of the face proper (the mimetic musculature in the strict sense) Although the great anthropoid apes—and this holds for chimpanzee and gorilla, as well as for the orangutan—have reached a considerably higher level than the gibbon showing quite a large range of individual features of expression, their facial expression is still rather crude and grimace-like while in this respect man has reached marvelous perfection. This phenomenon may be attributed to further differentiation of the "mimetic musculature" in close correlation with higher evolution of the central nervous mechanism, particularly with further development of the facial area in the motor cortex and through elaboration of association centers

bone forms the roof of the orbits assists in covering and protecting the brain and is joined along its base by the maxillofacial prism.

Muscles of Expression

The superficial facial muscles differ from other muscles of the body they do not act upon the underlying bones but control the movements of the soft tissues of the face (Figs. 13 14)

The muscles of expression are inserted into the dermis. The muscular fibers divide into a series of bundles of diminishing size upon reaching the deep layer of the dermis. These bundles penetrate the dermis to the base of the dermal papillae. The tendinous bundles terminate in a fan like manner immediately below the basal epidermal layer the diverging fibers insert into the dermal papillae and the basal layer of the epidermis (Fig 15)

The fibers may contract independently to produce fine shades of expression All the muscles of expression derive their nerve supply from the seventh cranial nerve

Some of the facial muscles the caninus and buccinator for example, are located at a deeper level than others (Fig 16)

The skin of the face forms folds under the influence of the contracting musculature usually at right angles to the direction of the muscle fibers muscle contraction forms curves or dimples where fibers insert directly into the dermis.

Facial expression is less apparent in childhood than in adult life for the muscles are not as well-developed and a thicker layer of subcutaneous fat is present.

The muscles of expression may be destroyed in deep wounds of the face, or inactivated by binding scar tissue immobility of a portion of the face is particularly disfiguring because of the contrast with the mobility of the rest of the face. The expression improves after the muscles are released from scar tissue and are again enabled *to function*. One of the serious limitations of reconstructive surgery following deep burns of

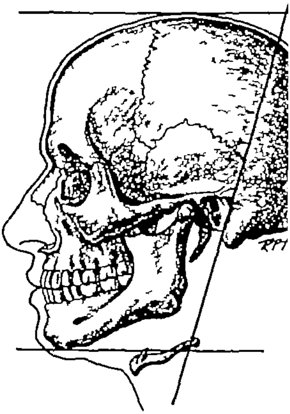

Fig 10 The facial area (drawn from the c
tion by Malgaigne)

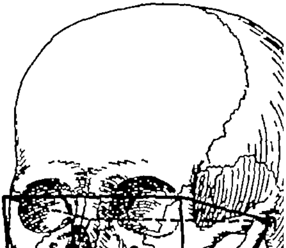

Fig 11 The maxillofacial prism

the face is due to destruction of the musculature, which results in an in
to restore the mobility of facial expr
The innervation of the muscles

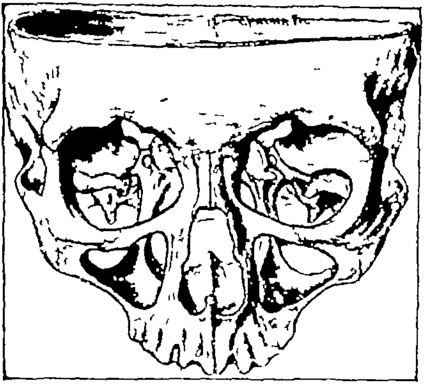

FIG 12. Drawing of a dissected skull. "The thinner bony portions have been removed leaving the heavier parts intact." (From H H Shapiro, *Applied Anatomy of the Head and Neck* Ed 2 J P Lippincott Co., 1947)

pression must be respected in reconstructive operations. The motor nerves enter the muscles in their deeper and more lateral portions severing the muscles around the mouth and lips is not usually followed by complete paralysis and atrophy of these structures, for when the continuity of the severed muscle is re-established, movements occur when the posterior portion of the muscle contracts regeneration of terminal filaments of the facial nerve in the severed portion of the muscle usually also occurs in such cases.

Muscles of Mastication

The temporalis (Figs. 17 18) masseter (Fig 17) and internal and external pterygoid muscles (Fig 16) are the principal muscles that move the mandible The masseter and temporalis muscles account in part for the contour of the face paralysis results in atrophy of these muscles and in a flattened appearance of the face. The muscles of mastication play an important role in mandibular fractures, for the fragments are displaced when the muscles contract (Figs. 100 101 103 Chapter 6)

Arteries of the Face

The superficial arteries of the face and scalp are the external maxillary transverse facial and superficial temporal branches of the external carotid artery (Fig 19) Branches of the external maxillary artery supply the chin lips, nose cheek and medial angle of the orbit. In designing a skin flap in the facial region one should be aware of the course of these vessels in order to preserve and incorporate them to ensure the viability of the flap. Branches of the superficial temporal artery nourish the outer parts of the upper cheeks, infraorbital supraorbital frontal and parietal regions. These superficial vessels join with branches of the internal maxillary a deep terminal branch of the external carotid and with

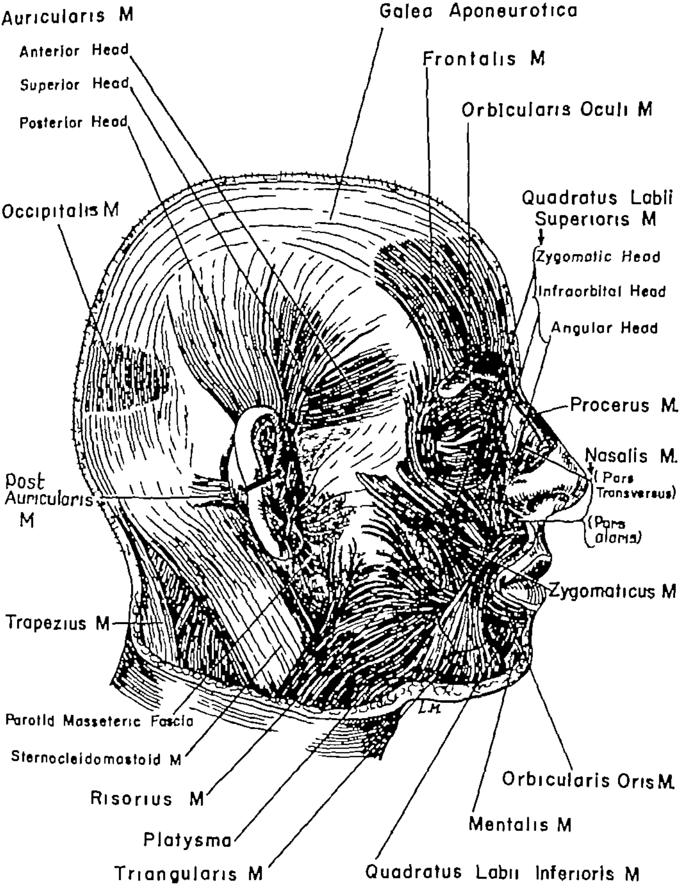

Fig 15 Superficial muscles of expression (lateral view)

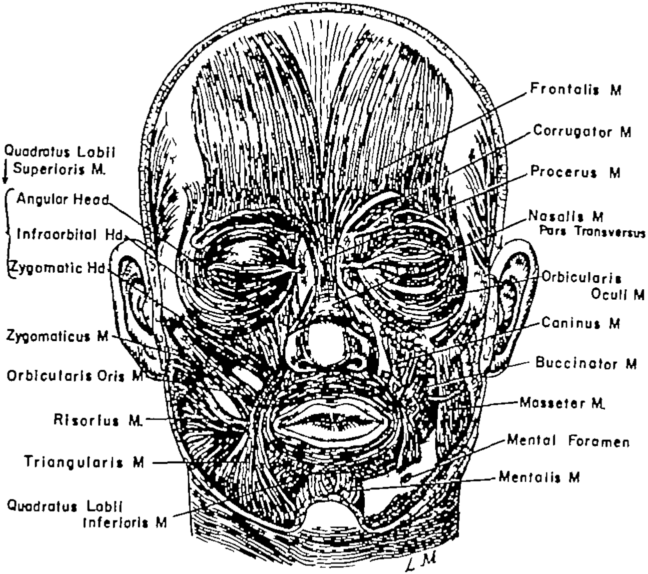

FIG 14 Superficial muscles of expression (anterior view) Note the deeper muscles of expression exposed on the left side.

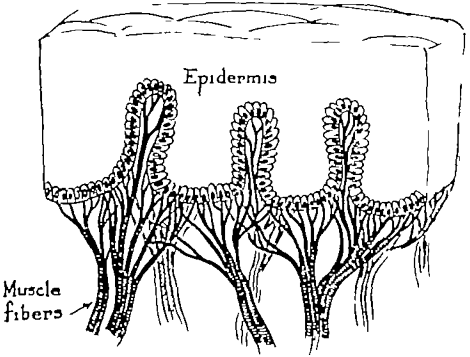

FIG 15 Insertion of the facial musculature of expression into the dermis of the skin of the face (after Testut) Note that the muscle fibers are divided into a series of bundles which penetrate to the dermal papillae and the basal layer of the epidermis.

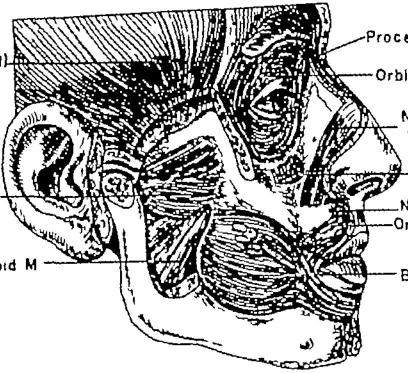

Fig 16 Deeper muscles of facial expression and the pterygoid musculature

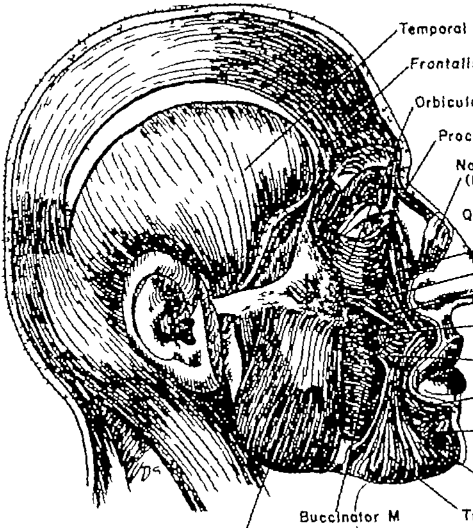

Fig 17 (*Above*) Muscules of mastication. Temporalis and masseter muscles

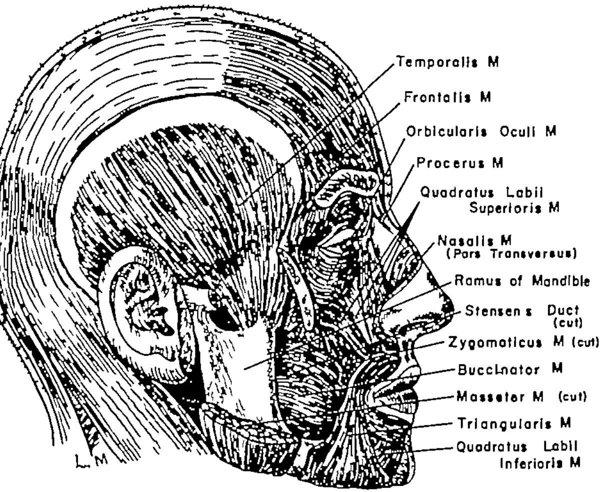

FIG 18 (*Below*) Muscles of mastication. Temporalis and masseter muscles. Note also the buccinator muscle penetrated by Stensen s duct.

terminal branches of the ophthalmic artery These vessels form a rich anastomotic network in the cutaneous and subcutaneous tissues of the face Ligation of the external carotid artery to control bleeding during major surgical procedures has been a fairly common practice The anastomotic channels in and about the oral cavity are so numerous that bleeding is not entirely arrested even after unilateral ligation. Permanent ligation of both external carotid arteries results in tissue devitalization and necrosis of the tongue If bilateral ligation is necessary an interval of several days should elapse between ligations for even after such precaution healing occurs slowly at the operative site Sugarbaker and Wiley (1951) advise simultaneous temporary ligation of both external carotid arteries in extensive surgical procedures to obtain a completely dry operative field and good healing after the release of the tourniquet. Figure 19 illustrates the superficial regional distribution of the main arteries of the face.

Venous Drainage

The anterior facial vein drains the blood from most of the face below the orbits the supraorbital vein aids the venous return to the ophthalmic vein. The superficial temporal vein also drains the forehead, emptying into the posterior facial vein the transverse facial vein drains the region of the zygomatic arch. These vessels communicate with the external jugular internal jugular and anterior jugular veins by means of an extensive anastomotic system

Lymphatics

The lymphatic vessels of the forehead and upper eyelids empty into the parotid nodes.

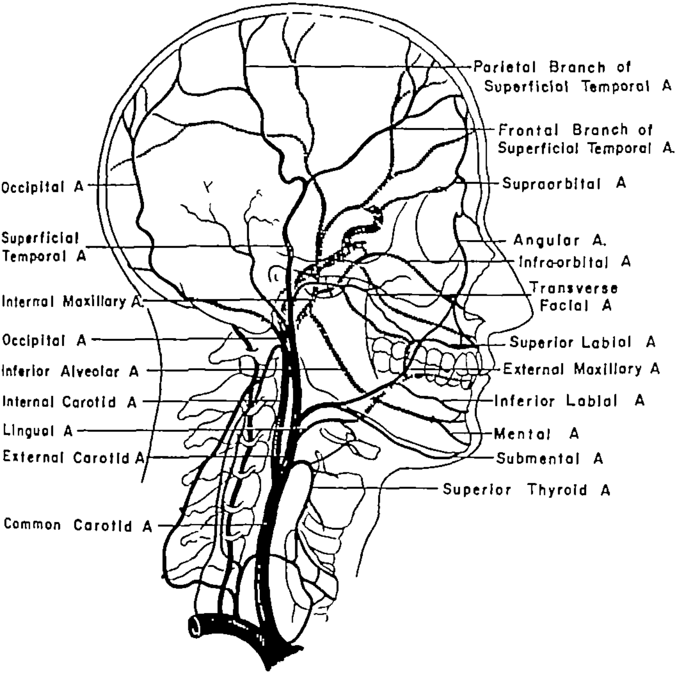

Fig 19 Arteries of the face and neck

Lymphatic drainage from the lower lid nose, cheek and upper lip reaches the buccinator and submaxillary nodes that from the lower lip and chin drains toward the submental nodes (Fig 20) Other lymphatic vessels from the face extend to the superficial and deep cervical nodes. Lymphatic obstruction may cause chronic edema of the lower eyelid for example if a wound or operative incision has severed the tissues around the orbit in a circular manner Weeks or months may pass before normal lymphatic circulation is re-established through the resulting scar

Innervation

The facial muscles receive their motor innervation by way of the facial nerve plexus in the parotid gland (Fig 21) the branches terminate in temporal zygomatic, buccal mandibular and cervical filaments.

The sensory innervation of the face is derived from the trigeminal nerve. The cornea iris lacrimal gland conjunctiva part of the mucosa of the nose, and the skin of the eyelids eyebrows, forehead and nose are innervated by the ophthalmic nerve. The side of the nose the lower eyelids and

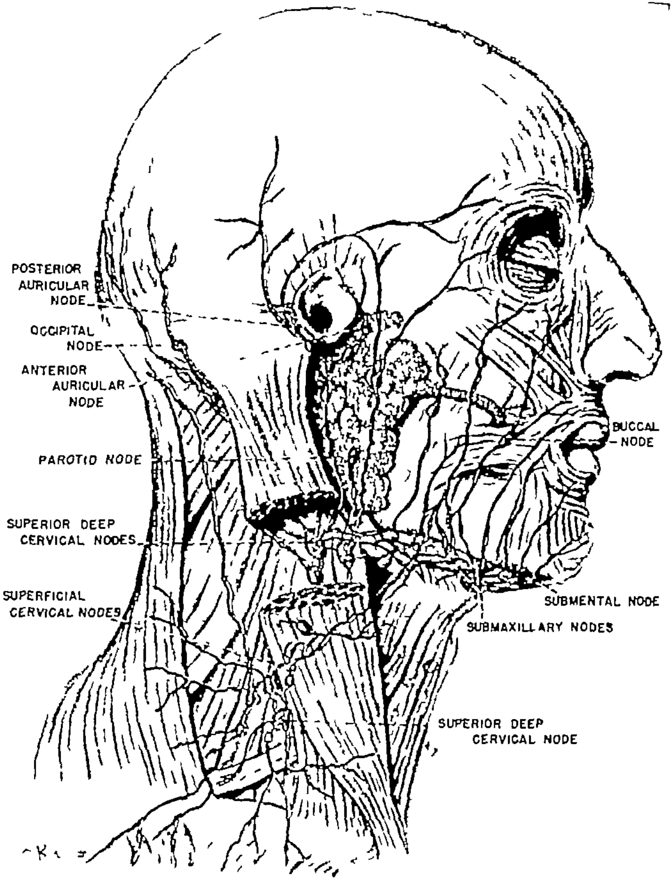

Fig. 20. Lymphatics of the face and neck. (From H. H. Shapiro: Maxillofacial Anatomy. J. B. Lippincott Co. 1954.)

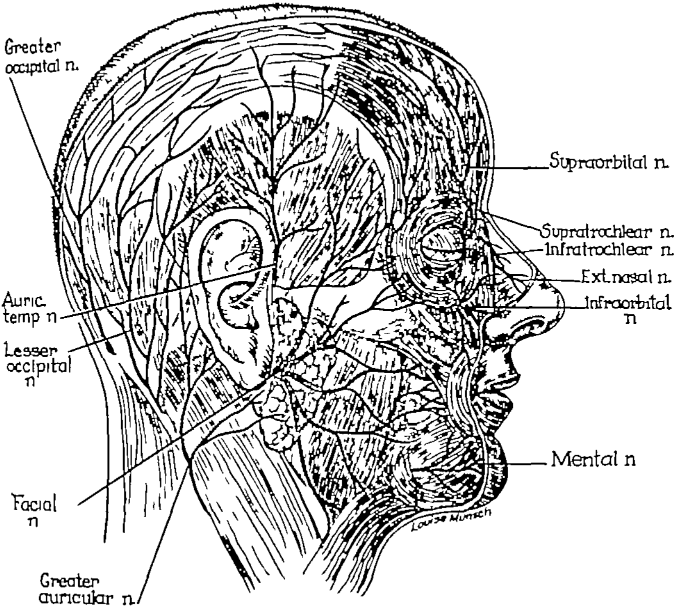

FIG 21 Nerves of the face

the upper lip are innervated by the maxillary nerve. The mandibular nerve third and largest division of the trigeminal supplies the teeth and gingiva of the mandible, the skin of the temporal region the ear lower lip lower part of the face, the muscles of mastication and the anterior two-thirds of the tongue.

Wounds or surgical incisions across the pathways of sensory nerves may result in temporary or permanent anesthesia of a portion of the face. Areas of anesthesia are usually transitory In local transposed or rotated pedicled skin flaps, the sensory innervation of the skin is interrupted over a major portion of the flap Complete interruption of the nerve supply to the transplanted skin may occur in flaps from a distance and in free skin grafts. The return of sensation in pedicled flaps is indicated by the onset of sweating which begins peripherally and gradually reaches the center of the flap The return of sensation varies from six months to one year in accordance with the size of the flap and to variable conditions such as the presence of scar tissue under or around the flap Sensory regeneration in skin grafts occurs over all parts of the graft simultaneously in a period of about one year (See Chapter 18 page 454)

Subcutaneous Tissue

The skin overlies subcutaneous tissue consisting of fat, intermingled with dense

fibrous and loose areolar tissue The superficial fascia containing the fat provides passage for cutaneous nerves, vessels, and lymphatics supplying the skin. The superficial fascia contains deep sweat glands, hair follicles, and lymph nodes in addition to the cutaneous musculature The fat layer of the face varies in thickness and is often intermingled with fibrous tissue In the upper lip in the vermilion border of the upper and lower lips, and in small areas near the margins of the upper and lower eyelids, little or no superficial fatty or fibrous tissue intervenes between skin and muscles.

The skin is mobile in some areas of the body and is adherent in others. In the lips, for example the skin adheres to underlying orbicularis oris muscle fibers the orbicularis oris is inserted directly into the skin and is intimately bound to the undersurface of the dermis. Dense subcutaneous collagenous tissue is found in five areas (Lightoller 1925) (Fig 22) the major portion of each of these areas also contains fatty tissue (1) an ovoid region surrounding both eyes (2) the tip and alae of the nose (3) the philtrum (4) the chin the lower lip and (5) the submandibular area The fat is concentrated in the region of the cheek above and lateral to the nasolabial fold and is thinnest in the forehead the upper and lower eyelids, the bridge of the nose and the lower lip. The area bounded by the nasolabial fold laterally and the labiomental fold inferiorly and occupied by the mobile lips, contains little or no fat but is bounded by the fatty envelope of the cheeks. The fat layer of the face tends to melt away in malnutrition and in old age the excess skin forms folds from having lost its elasticity

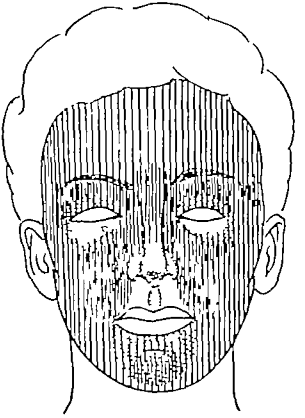

Fig. 22 Distribution of subcutaneous fat and fibrous tissue in the face Dotted area represents presence of thick connective tissue vertical lines represent fat which varies with thickness of lines. In some areas the fat is accompanied by dense connective tissue In these areas both dots and lines are present (after Lightoller)

Areolar Tissue

Areolar tissue a loose network in a semifluid gelatinous substance connects the skin and subcutaneous tissues with underlying structures.

Microscopic examination of areolar tissue reveals bundles of many white fibers, and yellow elastic fibers which follow a straight course The skin is mobile over the underlying structures in areas where areolar tissue is plentiful as in the eyelids where the excess skin forms numerous folds.

The Skin

The skin constitutes a barrier against disease organisms and plays an important role in regulating body temperature Vasoconstriction of skin capillaries prevents loss of heat vasodilation facilitates heat loss. The skin also contains many sensory nerve endings.

The two layers of the skin are derived from different embryonic layers and differ in character (Fig 23) The outermost thinner layer is the epidermis the innermost

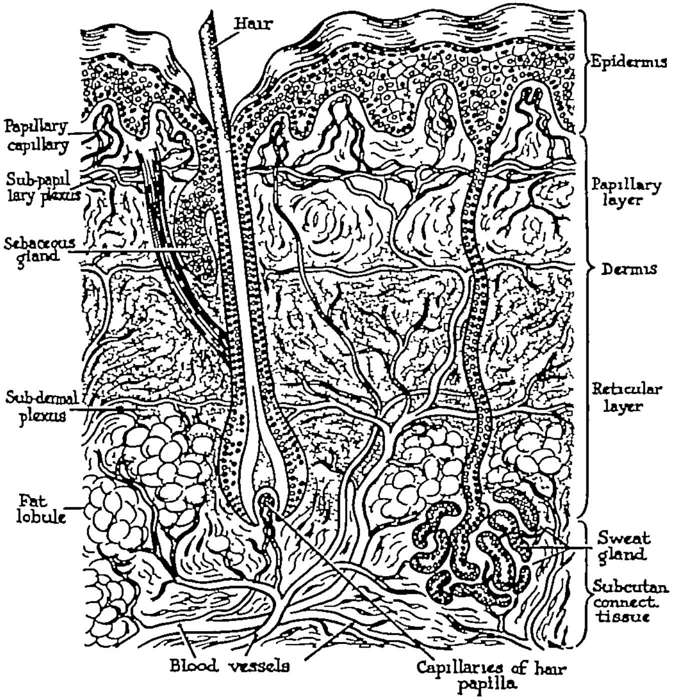

FIG 23 Diagrammatic section of the skin

thicker layer is the dermis, which consists of connective tissue. The two layers are intimately connected by means of fine elastic fibers these can be dissolved by a trypsin preparation (Medawar 1941) The epidermis, containing no blood vessels, derives its blood supply from the dermis. The dermis, acting as the nutrient membrane of the epidermis, is thus indispensable for the epidermis this relationship is well-demonstrated by the fact that epithelial cells grown in sheets on tissue culture rarely survive when again transplanted to the original donor

Epidermis

The cells of the epidermis are arranged in layers which are not clearly defined and can probably be considered as separate steps in a continuous evolution from the basal to the outer cornified squamous layer The basal layer also called the stratum germinativum is located next to the dermis and its blood supply The stratum spinosum is su

perficial to the basal layer and is also referred to as the Malpighi stratum or prickle-cell layer in which the cells are larger and are joined by tiny fibrils known as tonofibrils. More superficially the cytoplasm of the cells contains granules, and is known as the stratum granulosum Immediately above this layer is a clear lucid appearing band known as the stratum lucidum The outer layer of the epidermis is the cornified stratum corneum which is being desquamated and replaced continually from underlying dividing cells.

The multilayered structures of the epidermis are found in the thick skin of the palms and soles the epidermis is considerably thinner over the rest of the body The stratum corneum and stratum germinativum are the only layers constantly present in all parts of the body

Epidermal tissue is subjected to trauma more readily than other tissues of the body The epidermis usually withstands these environmental impacts because of periodic exposure to solar radiation wide variations in temperature cuts, scratches, burns, bacteria and viruses. On the distal surface of the epidermis a coat of keratin unusually insoluble and tough protects the body from the environment. Keratin does not cover the soft, stratified squamous epithelium of the oral and nasal cavities.

Epidermis undergoes growth and replacement throughout life (Storey and LeBlond 1951). New cells produced by these mitoses exert a pressure which results in a movement of the cells to the surface (Flemming, 1884) extruding cells are transformed into a horny material which forms the keratinized layers. The keratinization may be soft as in the skin or hard as in the nails or hair cortex The nails of the fingers grow more rapidly than those of the toes, approximately 1 mm per week in the former compared to 0.25 mm in the latter Hairs of the leg grow at a weekly rate of about 1.5 mm. those of the pubic and axillary region grow 2.2 mm in the same length of time. Hair growth is continuous in onl few instances. It has been calculated tl the renewal time of the Malpighian la is about 19 days. Thus, each epidermal c spends an average of 19 days in its excursi to the surface.

Dermis

The dermis consists of two layers, a perficial or papillary and a deep or reti lar layer The papillary layer is formed fine connective tissue fibers intermingl with elastic fibers arranged in ridges papillae these contain the terminal ca laries and the organs of touch.

The reticular layer is formed of clos interlaced fibrous and elastic tissue fib The reticular fibrous bundles in the derr extend parallel or obliquely to the skin s face.

Many fine furrows form a close netwo on the surface of the skin of the face. T small rhomboid ridges in which the orifi of the sweat glands are grouped separat by fine grooves, depend on the arrangeme of the dermal papillae in the dermis (Un 1885) The surface elevations are associat with the higher papillae and the furro with lower papillae

Dermis consists of connective tissue bu dles, elastic fibrils and ground substan An interlacing fabric of bundles can seen under polarized light (Robb-Smi 1954) these are formed of collagen t principal fibrillary component of conn tive tissue these bundles are seen to co sist of oriented fibrils under polarized ligl Another of the fibrillary components connective tissue is the network of elast fibers which are revealed when stained the dermis is examined under high magni cation when impregnated with silver sal the denser particles of collagen stain a ligl golden brown and are not so conspicuou in photomicrographs as the finer blac fibrils of reticulin If a section is treate with periodic acid followed by Schiff's re gent which reveals the presence of carb

rate, the spaces between the collagen n faintly those around the reticulin als stain a more intense red revealing presence of a non fibrillary matrix of ound substance with a variable carbohy ate content.

Collagen fibers show characteristic cross iations when examined with the electron icroscope. The chemical content of colla n is a polypeptide in which a third of its sidue consists of the amino acid proline id hydroxyproline and a third of glycein gether with a small amount of carbohy rate. Collagen when boiled is hydrolyzed) gelatin its soluble disoriented form Robb-Smith 1954)

Elastic tissue is distributed throughout he dermis and is closely interlaced in the eticular layer The nature of the elastic issue is somewhat obscure chemically it is a polypeptide with a high content of glycein alanine and valine, but the very low con tent of polar residues and x ray defraction of the molecules may indicate disorienta tion.

The ground substance consists in part of extracellular fluid derived largely from the blood plasma and contains mucopoly saccharides, chiefly hyaluronic acid and chrondroitinsulphates and glycoproteins, in a varying degree of polymerisation. The ground substance ordinarily has a gell like consistency the proportion of ground sub-stance decreases with age being replaced by fibrous intercellular tissue (Ham 1953)

Hair Follicles

Cells of the developing epidermis invade the dermis during embryonic development to form intradermal epithelial structures, the hair follicles, sebaceous glands and sweat glands. These structures are the source of a new epidermal layer when the covering epidermis has been removed or destroyed

The downgrowth of epidermis into the underlying dermis begins early in the third month of fetal life. The fetus at about the sixth month has become covered with deli cate hair (lanugo) This hair is shed before birth except in the region of the eyebrows, eyelids and scalp where the hairs persist and become somewhat stronger These hairs are replaced by coarser ones a few months after birth A new hairy growth occurs over the rest of the body which becomes covered with a downy coat, the vellus. Coarse hair is developed at puberty in the axilla the pubic region and on the face in males and to a lesser extent on other parts of the body A small bundle of smooth muscle fibers the arrector pili is attached to the connective tissue sheath of the hair follicle and extends upward to reach the papillary layer of the dermis near the mouth of the hair follicle. Muscle contraction pulls the hair follicle outward and acts upon the sebaceous glands, expressing their oily secretion (Hamilton 1951)

In transplanted skin the growth of hair in an area which should be hairless creates problems. The stimulus for the abnormal growth of hairs in transplanted skin is not known

Hair tracts in the human head are shown in Figure 24 the skin of the eyelids con

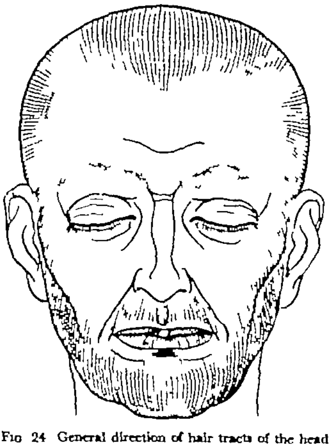

Fig 24 General direction of hair tracts of the head

tains no hair follicles. Hairs do not grow vertically from the skin but assume a slanting direction this fact merits consideration when transplanting hair for the reconstruction of an eyebrow the incisions should be oblique in order to be parallel to the direction of the hair follicles.

Sebaceous Glands

The openings of the sebaceous glands are located at the junction of the middle and upper third of the hair follicles (Fig 23) These racemose or saccular glands are generally found on the under side of the hair follicles, but away from the hairs on the lips, buccal mucosa and lacrimal caruncles they attain a large size in the skin over the lower half of the nose. The lobules of sebaceous glands are solid masses of cells which gradually become filled with fat granules and finally disintegrate giving forth an oily secretion known as sebum, which provides a lubricant for the hair and keeps the skin supple protects it against friction and makes it more impervious to moisture.

Sweat Glands

These are simple, tubular glands, usually coiled at the base of the dermis (Fig 23) The ducts of the sweat glands pass through the epidermis and open at the sweat pores on the surface of the skin or above the opening of the sebaceous glands in the walls of the hair follicles.

The density and distribution of sweat glands vary in different parts of the body The glands are most abundant in the palms of the hands and soles of the feet, in the axilla and in areas of the face such as the nose and forehead

A peculiar hyperactivity of sweat glands occurs in transplanted skin as the result of emotional sweating and also in injured skin such as healed burned areas. Such sweating is often observed in patients during the clinical examination when the emotional reaction is marked by sweating of the hands, forehead and nose. Sweating can be induced as the result of heat, mental or emotional stress, or by basal secretory activity

Transplanted skin temporarily severed from nerve connections, lacks the lubrication normally supplied by sebaceous and sweat glands and is therefore dry and more susceptible to injury Bland ointments such as lanolin and olive oil should be applied to grafted skin until reinnervation and function of the secreting glands is restored.

The Junction of Dermis and Subcutaneous Fat (Superficial Fascia)

The area of junction of dermis and subcutaneous adipose tissue is irregular Domes of fat, the columnae adiposae project into the lower layers of the dermis and bands of dermal collagen extend into the subcutaneous tissue between the fat domes. When sections of skin are cut in a plane parallel to the surface of the skin at the level of the junction between dermis and fat, the pattern is that of a collagen net the fat protruding through the spaces of the meshwork.

Many hair follicles, with their arrector pili muscles, are implanted into the summits of the fat domes, two or three to each dome. Most of the sweat glands are situated between the fat domes and the collagen bundles. They are usually placed at a deeper level than the hair follicles in the bearded area of the male face, however hair follicles are implanted into the subcutaneous fat below the level of junction with the dermis. The irregular line of junction between dermis and fat, and the presence of deeply situated epidermal structures account for the epithelization which occurs in burns of the face in which the cutaneous layer is apparently destroyed.

Blood Vessels of the Skin

The epidermis contains no blood vessels. No bleeding occurs when thin shavings are cut from the surface of the skin but hemor

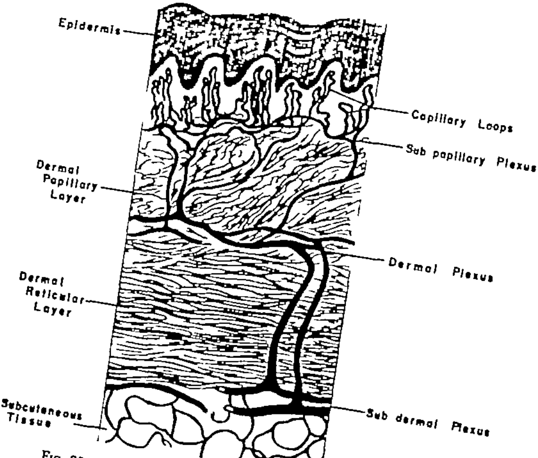

FIG 25 Schematic representation of the blood vessels of the skin

rhage does result when the capillaries of the dermis are cut.

The arteries supplying the skin form a characteristic cutaneous arterial network at the junction of the dermis and subcutaneous fat (Fig 25) Arched and branching vessels from this network form a subpapillary arterial network. Numerous small branches from the subpapillary network send twigs, terminal arterioles, to the superficial layers of the dermis and to the arterial limbs of the capillary loops in the dermal papillae. The venous blood returning from the dermal papillae flows through three successive venous networks to still another network behind the junction of the dermis and subcutaneous fat (Spalteholz, 1893)

The arteries of the cutaneous arterial network possess a thick muscular coat which diminishes in thickness in the more superficial arterioles which are lined by a single layer of muscle cells (Spalteholz, 1927) Superficial vessels are formed of endothelium only muscle cells appear in the deeper veins valvulae and a free muscular coat appear in the subdermal plexus. The muscular coat is replaced by contractile Rouget's cells, according to Vimtrup (1923) The terminal arterioles capillaries collecting venules and the subpapillary venous plexus vessels that are visible in the skin *in vivo* by stereomicroscopy have been termed minute vessels by Lewis (1927)

The vascular network of the skin of the face is rich and finely meshed particularly in the regions of the auricle lips and cartilaginous portion of the nose The blood supply of the dermal plexus accounts for the maintenance of vascularization of extensively undermined skin flaps.

Elasticity of the Skin

Skin possesses a degree of elasticity owing to the presence of elastic fibers in the dermis. Elastic fibers are disposed in bundles with the collagenous fibers and are dis-

tributed through the dermis becoming finer toward the surface of the dermis. The elasticity maintains the skin in a state of constant tension This is demonstrated by the gaping of wound edges following incision and also by the immediate contraction of skin grafts the thicker the skin graft, the greater the amount of elastic tissue and the more contraction The elasticity of the skin facilitates the shifting of skin flaps. Degeneration of elastic tissue in the skin of the aged is responsible for the relaxation of the skin of the face and the formation of excess skin folds.

LINES OF TENSION AND LINES OF FLEXION The collagen and elastic fiber bundles of the skin are arranged along the lines of Langer (1861) The existence of lines of tension in the skin was first noted by Dupuytren (1832) in describing wounds of the skin made by penetrating instruments. He reported a case of a cobbler who committed suicide by stabbing himself with an awl the awl was pointed at the tip and round in section but the wounds in the cobbler's skin were linear in outline as though made by the blade of a knife.

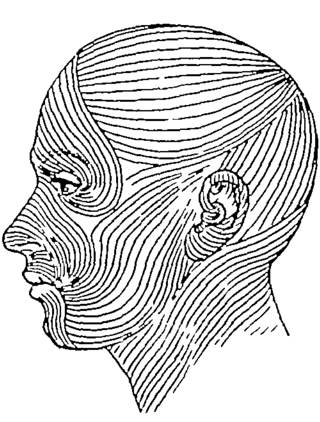

Fig 26 Langer's lines of tension

Langer (1861) found that following puncture of the skin in various parts of the body the puncture holes had a tendency to open in a direction corresponding to the normal tension of the skin. Langer considered that human skin was less tensible in the direction of the lines of tension than across them. He attributed this fact to the structure of skin which he described as consisting of a network of rhomboid meshes permitting greater tension in the direction of the shorter diameter When placed under tension the fibers straighten and the meshes are stretched the fibers themselves are stretched when tension is continued. Ragnell (1954) corroborated Langer's statement by demonstrating that the tensibility of human skin is approximately one third greater at right angles to the lines of Langer than it is along them

The predominant direction of the collagenous and elastic fiber bundles accounts for the Langer's (or tension) lines of the skin (Fig 26) An incision at right angles to these lines tends to gape a wound at right angles to these lines is submitted to constant pull during healing Sections of skin made in two planes (Cox 1911) one exactly at right angles and another exactly parallel to the long axis of a wound indicate a striking difference in structure according to the plane of the section Sections at right angles to the long axis of the wound show a marked preponderance of connective tissue and elastic fibers cut transversely sections parallel to the long axis of the wound show that the majority of fibers extend longitudinally (Fig 27)

The lines of tension coincide generally with the crease lines of the face In the nasolabial fold, for example the fibers lie longitudinally within the fold a few short fibers form a network between them

The skin may be compared to a membrane which is under greater tension in one direction than in another a hole produced

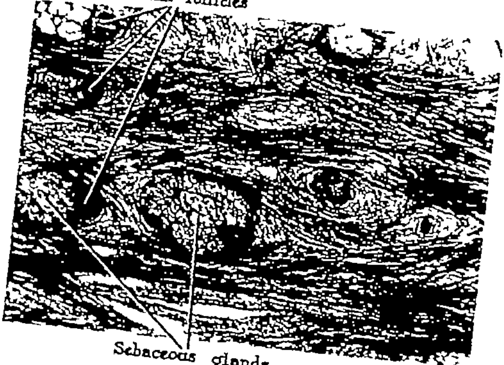

Fig 27 Postauricular skin of male age 14 Section parallel to the skin surface at the level of the sebaceous glands shows the direction of the lines of tension. Collagen and elastic fibers are arranged in a parallel fashion to the lines of Langer (Courtesy of D T Shaw and W M. Copenhaver)

by an instrument round in section assumes an elliptical shape in the direction of the greater pull. In an accidental wound gaping is increased if the wound extends across the lines of tension of the skin Elective incisions should therefore be placed along the direction of Langer s lines to obtain rapid healing of wounds and minimal scarring due to the absence of tension along the healing wound.

The lines of tension of the skin which are manifest in repose, are due to a functional arrangement of the collagen bundles of the dermis. Thus is evidenced when a skin graft is removed from its bed contraction of the graft is maximal in the direction of Langer s lines.

The premise that wounds heal more rapidly and with less scarring when their long axis lies parallel to Langer s lines has not been verified in practice. Gaping can be increased if the wound is at right angles to the direction of an underlying muscle of expression In a deep horizontally placed wound of the forehead, for example gaping is accentuated by the pull of the sectioned portions of the frontalis muscle. Hypertrophic scarring may occur when incisions are parallel to the lines of Langer as in the construction of a tubed pedicled flap in the neck. Only a slightly visible scar results when incisions in the neck are made within a skin fold or crease, or are parallel to the fold for the skin around the folds is loose and redundant considerable width can be excised on either side of the incision parallel to or in the folds without materially increasing tension when the wound is closed. In addition to Langer s tension lines of the skin the lines of flexion must be considered these are referred to as folds of expression

Facial wrinkles are produced by repeated and habitual contraction of the underlying muscles of facial expression (Fig 28) Wrinkles are caused by shortening of the muscle without corresponding shortening of the skin the skin adapts itself by forming folds at right angles to the line of contraction of the underlying muscle (Kraissl and Conway 1949)

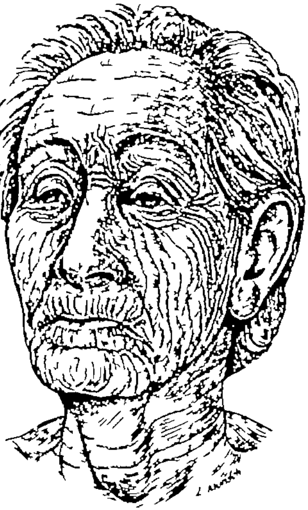

FIG 28 Drawing illustrating the lines and folds of expression of the human face. Compare the direction of the folds of expression with the direction of Langer's lines (see Fig 26)

In some regions a number of muscles act in unison the wrinkles of the skin form a curved line The nasolabial fold for example represents the area of junction between the skin of the lip which is tightly bound to the underlying orbicularis oris muscle and the more loosely bound skin of the cheek over the buccal fat pad the nasolabial fold is also formed in part by muscular contraction of the zygomaticus, quadratus labii superioris and caninus muscles the risorius and buccinator muscles also play a role in the production of this groove

The supraorbital wrinkle lines are caused by the contraction of the frontalis muscle which is inserted into the skin of the lower forehead. The transverse lines of the forehead are due to the contraction of the frontalis muscle the skin adapts itself to the contracted muscle fibers, forming folds of excess skin Many fine perpendicular strands of connective tissue in the upper eyelid terminate in the dermis of the skin to form the tarsal fold these tissue strands represent the insertion of the levator palpebrae superioris muscle. Similar tendinous insertions in the lower lid are from smooth muscle and also insert perpendicularly creating the fine horizontal lines of the lower lid which are accentuated by the contraction of the orbicularis oculi muscle The sphincter action of the orbicularis oculi muscle is altered by its origin and insertion at two fixed points, the palpebral ligament at the inner canthus and the lateral palpebral raphe at the outer canthus. Contraction of this portion of the muscle results in lines at right angles to the direction of its fibers the wrinkles are at right angles to the action of the muscle At the upper portion of the dorsum of the nose the corrugator supercilii and orbicularis oculi muscles act somewhat antagonistically to the frontalis to form the almost vertical lines observed during the act of frowning

The oblique lines on the side of the nose are due to the action of the angular head of the quadratus labii superioris and the procerus muscles. The vertical lines in the lower part of the nose are due to the contraction of the transverse portion of the nasalis muscle The orbicularis oris muscle, a true sphincter has no fixed points the crease lines develop radially from the oral aperture At the angles of the mouth however the combined action of the quadratus labii superioris and of other muscles in this region cause the lines to blend with those of the nasolabial fold The formation of the lines on the outer aspect of the chin results from the action of the triangularis, quadratus labii inferioris and mentalis muscles. The transverse lines mainly horizontal in the upper and lateral portion of the cheek

are due to the action of the temporalis muscle.

The transverse lines across the neck are due to the folds of excess skin permitting extension of the neck. The horizontal neck lines become more oblique toward the chest.

Every individual possesses lines of expression that become more apparent when the muscles contract. Wrinkles are less evident in young individuals creases and wrinkles are increased in old age because the skin, through degenerative changes has lost its elasticity and is incapable of assuming its smooth appearance at the termination of muscular contraction.

Langer s lines of tension and the folds of expression are paralled in many areas in others they diverge. A scar across a fold of expression is constantly subjected to stress during muscular activity causing trauma and microscopic hemorrhage, inflammation and eventual fibrosis and thickening of the scar Changing the direction of the scar by Z-flaps in such cases prevents the recurrence of thickening of the scar by lengthening and also by changing the direction of the scar tissue so that the flaps are spared the pull of the muscles.

The lines of flexion or of expression constitute the best guide to the placing of incisions scars parallel to or within these skin creases are the least visible.

Thickness of the Skin

The depth of the skin varies from 0 4 mm. to 3 0 mm. in different regions of the face. It is thinnest in the eyelids and thickest in hair-bearing regions, principally in the scalp and the region of the chin The thickness of the skin and subcutaneous tissue can be grossly estimated by testing a fold of the skin between forefinger and thumb

Measurements of skin thickness have been made by Barker (1951) Southwood (1955) González Ulloa, Stevens, Fuertes and Leonelli (1957) Skin thickness varies from less than 400 microns (0 01575 inch) for thin skin found in the eyelid to thick skin measuring over 3000 microns found over the back (0 11811 inch)

The thickness of the epidermis varies from 0 02 to 1 4 mm. (0 00078 to 0 05511 inch) that of the dermis varies from 0 40 to 2.4 mm. (0 01575 to 0 09842 inch)

The skin is relatively thin at birth and becomes thicker at about the time of puberty maintaining its thickness until about the fifth or sixth decade, when it again becomes thinner the thinning of the epidermis is accompanied by reduction in the size of the papillae

The dimensions of skin thickness are smaller in children therefore thinner grafts than in adults are cut in order to avoid removing the entire skin thickness. The thickness of the adhesive cement used with the dermatome technique is approximately 0.5 mm.

Color of Skin

Discrepancy in color between transplanted skin and the adjacent skin of the face may mar an otherwise successful operation. It is difficult to obtain a comparable color match when skin is transplanted from a distant area for the color and also the texture of the skin becomes more dissimilar to the skin of the face as the distance between the donor area and the face increases. Because of this efforts should be made to transplant skin from neighboring areas. Attempts to improve the color of dissimilar skin by tattooing have not yielded satisfactory results although some improvement results, the method is not a reliable one.

The color of the skin is determined by the granular layer of the epidermis and the reflection of light from the granules of that layer for the skin is translucent. Skin color is also determined by its texture, by the degree of constriction of the blood vessels of the skin and by the hemoglobin content of the blood. The thinner the granular layer the redder the skin will be as the underlying blood vessels are more apparent.

Mucosa having no granular layer is more transparent and consequently redder than skin

Edwards and Duntley (1939) analyzed the color of the skin by means of the Hardy photoelectric recording spectrophotometer Light striking the body appears to penetrate the entire skin down to and including the subcutaneous fat. The color of the skin is represented by the total reflected light which remains after the absorption of a number of wave lengths by the pigments in the different layers of the skin The pigments are melanin melanoid (a derivative of melanin) oxyhemoglobin reduced hemoglobin and carotene The turbidity of the deeper layers of the epidermis furnishes the added effect of scattering, or re arrangement of light, which has an important influence on the coloring

Melanin is present in the form of granules in the basal layer of the cells of the epidermis it exists in lesser quantity in the melanophores of the dermis. Variations in the amount of melanin in the epidermis are *responsible for the differences in racial* coloration Melanoid is a substance allied to melanin which is present throughout the epidermis and gives the skin its yellow color it is especially abundant where the epithelium is thick as in the sole of the foot where the stratum corneum is thicker than in any other region of the body Carotene is found in the stratum corneum of the epidermis, in the fat of the dermis and in subcutaneous tissue.

The blood contains a number of pigments the most important of which is hemoglobin present as a mixture of oxyhemoglobin and reduced hemoglobin The skin reflectants are influenced by the superficial subpapillary vascular plexus and by the capillaries of the papillae In the skin of the face and neck red areas indicate greater vascularity and thus a greater concentration of hemoglobin in a given area

All of these pigments absorb rather heavily in the blue end of the spectrum and therefore appear more red than otherwise. The skin does not appear dark red because of the "scattering phenomenon occurring within the deeper layers of the epidermis. "Scattering" raises the blue end of the reflected spectrum The quantity of light which is transmitted contains a greater proportion of red while that which is reflected contains a correspondingly larger proportion of blue Since the whole epidermis varies considerably in thickness in different parts of the body the degree of "scattering also varies as does the distribution of pigment Pigment is massed in large quantities in the dermis or subcutaneous tissue *This accounts for the blue color of* the shaven male cheek as the pigment masses in the diagonally placed hair bulbs absorb the light and prevent transmission to the deep dermis and subcutaneous tissue and its reflection from these layers. Melanin arterial blood and carotene are more heavily distributed in the head than in the rest of the body Females have whiter skin with less melanin and blood than males, but with more carotene The nape of the neck in the female is more deeply pigmented by melanin

2

HEALING OF WOUNDS

The success of surgical procedures depends largely upon the capacity of the body to restore the continuity of injured tissues the role of the surgeon in this vital process is to enable these strategies of repair to perform their innate functions with rapidity and effectiveness.

HEALING OF CLEAN INCISED AND SUTURED WOUNDS

The process of wound healing consists of a continuous and progressive series of events which are initiated immediately after injury The first of these is the reaction of the tissues to the injury Somewhat hampered in the beginning by the inflammatory response to tissue reaction proliferation of connective and epithelial tissues proceeds with gathering impetus. A binding material collagen appears to be responsible for contraction of the wound and assures its tensile strength.

A clot containing strands showing the staining characteristics of fibrin erythrocytes and a few leucocytes fills the interstices of the wound. Following surgical incision of the tissues, inflammatory edema occurs around the incised area and leucocytes migrate into the injured tissues. Devitalized tissue is digested by enzymes liberated by the leucocytes, and macrophages invade the clot, ingesting the remnants of fibrin and red cells.

Capillaries, originating from proliferating blood vessels around the periphery of the wound, follow the macrophages, advancing into the clot. The first new blood vessels are formed by buddings of the endothelium of the pre-existing blood vessels. The capillary sprout in its early stage is a solid protuberance with a fine terminal prolongation (Sandison 1928) The solid capillaries develop a lumen and blood flows through the newly formed capillary loop

The period of inflammatory reaction immediately following injury has been named the latent period of wound healing by Carrel and Du Noüy (1921) indicating that regenerative processes are at a minimum during the early reaction of the tissues to injury Cellular proliferation as indicated by the presence of mitoses, is initiated as early as 36 hours after injury and thereafter is a continual process. The so-called latent period is prolonged in the presence of damaged tissue or foreign bodies. The rapidity of wound healing may often be dependent upon the amount of tissue damage incurred it is minimal in clean incised wounds and also of short duration in areas, such as the face, which have a rich blood supply

Cellular Proliferation

New tissue is formed by cellular proliferation of two types connective tissue cells which restore the continuity of the deep structures by fibroplasia and epithelial cells which restore the surface of the wound

Proliferation of Connective Tissue

Active division occurs of two types of cells connective tissue cells and vascular endothelial cells.

The fibroblast is a narrow nucleus surrounded by a thin layer of cytoplasm wedged between dense bundles of collagen fibers the cell increases in size and exhibits branching processes. There has been controversy concerning the origin of the cells involved in wound repair Most workers have been of the opinion following Marchand (1901) that the repair of wounds is provided essentially by the multiplication of cells in and around the wound. Maximow (1902) expressed the view that circulating blood cells of the leucocyte series played an active role in wound healing by providing new connective tissue cells. Cells of diverse mononuclear nongranular ameboid and phagocytic appearance have been described as polyblasts by Maximow He considered a change of polyblast to fibrocyte a possibility Maximow's theory has been discussed in many reviews of the subject of wound healing including the extensive review by Arey (1936) Recent work and a review by Allgöwer (1956) cite two types of experimental data in favor of Maximow's theory (1) extensive reduction in the number of blood cells by total body irradiation resulted in a fifty to seventy per cent decrease of granulation tissue, and (2) *in vitro* culture of human and animal leucocytes indicated the ability of certain mononuclear leucocytes to produce connective tissue networks.

The origin of collagen has been the subject of recent research Stearns (1910) observed that fibroblasts showed small cytoplastic masses from which collagenous fibers arose. Porter and Vanamee (1919) using the electron microscope, observed an interaction between the fibers laid down on either side of the cellular membrane and materials in the ground substance. *In vitro* studies of Highberger Gross and Schmitt (1951) showed that a dialyzed acid solution of collagen becomes a collagen fiber in the presence of an acid polysaccharide such as chondroitinsulfuric acid.

It has been postulated that fibroblasts secrete a soluble protein precollagenous substance essential for fiber formation but that the process is not complete without the presence of a carbohydrate fraction in the ground substance. One explanation of the origin of the mucopolysaccharides in the ground substance is that fibroblasts secrete them (Meyer 1947 Curren and Kennedy 1955) another maintains that they are the product of mast cells (Asboe Hansen 1955).

New vascular channels or capillaries are formed of endothelial cells only Endothelial tubes acquire a muscular coat forming arteries. Endothelial buds, arising from pre-existing capillaries stretch into the fibrin mesh and lymphatic capillary proliferation follows that of the blood vessels (Pullinger and Florey 1937) Fibroblasts, guided by filaments of fibrin begin to branch and deposit collagen fibrils.

A minimum amount of clot is left between wound edges when they are brought together with precision thus resulting in a fine scar Tension on sutures causes strangulation of tissue and necrosis of the wound edges. Although tenuous, the collagen fibrils are sufficiently strong to prevent separation of the wound edges after two to four days, especially when the tissues are approximated without tension The sutures maintain the wound edges, preventing motion and rupture of the clot while young fibroblasts bridge the gap larger collagen fibers appear later thereby strengthening the area of repair

Proliferation of Epithelial Tissue

Epithelium spreads from the edges of the wound over the proliferating connective tissue through a process of cellular enlargement division and migration thus reestablishing the continuity of the epithelial surface the spread occurs through the intermediary of a coagulum of plasma that dries on the surface to form a crust or scab which covers and protects the newly grown epithelium (Arey 1936) The scar should therefore be left undisturbed and dry in order

to permit the fulfillment of its protective role unless underlying suppuration warrants its removal Moist dressings should be applied to hasten spontaneous detachment of the scab if beads of pus appear from beneath the sides of the crust.

New epithelium consists of a single layer of cells which differentiate rapidly into numerous layers. Young scars appear pink or red because they are cellular and vascular and are covered only by thin and translucent epithelium. As the number of vessels is reduced the connective tissues becomes more collagenous and the scar thicker the scar appearing gray in color and then white old cicatrices often become pigmented

Maturation of the Scar

After the initiation of fibroblast proliferation tenous fibrils of collagen appear these are followed by thicker fibers. Formation of collagen supplying tensile strength to the wound is dependent upon two factors (1) a protein component probably produced by fibroblasts, passes through several stages to form collagen and (2) a carbohydrate component, a complex mucopolysaccharide produced either by mast cells or connective tissue cells, which forms a homogenous matrix, a chemical and physical requirement for the ultimate deposition of collagen from the protein component. An initial period of shock, of not more than twelve to twenty four hours duration, is followed by rapid production of ground substance which reaches a peak between the third and sixth day (Dunphy and Udupa, 1955) It is thought that soluble protein precursors of collagen formed during this productive or substrate phase due to the presence of reticular silver staining fibers, are demonstrated in significant quantities by the fifth day Observations by Gould and Woessner (1955) indicate that glycine and proline the important amino acids involved in collagen formation are present in large quantities during this phase.

Under normal conditions, the scar becomes less vascular less cellular and paler gradually shrinking during maturation Shrinkage accounts for the depression found in some scars, and for distortion of the surrounding tissue The collagenous tissue of the scar may remain deprived of elastic tissue for lengthy periods for two years in some instances. The scar generally contains no hair follicles sebaceous glands adipose tissue or tactile corpuscles (Leriche and Howes 1931)

Wounds sutured under tension may widen The connective tissue may continue to proliferate after the completion of epithelization thus forming hypertrophic or keloidal scars

Wound Contraction

Contraction of the wound has been attributed principally to a shortening of the maturing fibrous tissue. The vessels disappear as the cell population decreases the wound then consists of thick collagen fiber bundles with a few compressed nuclei of the original fibroblasts retained between them This process may produce contracture deformities in areas where the tissues are loosely bound to underlying structures. The role of the granulation tissue in wound contraction has been questioned in more recent investigations According to Watts, Grillo and Gross (1958) the machinery for the major part of contraction lies in the wound margin and the central granulation tissue is not required in the process of contraction

HEALING OF WOUNDS WITH LOSS OF TISSUE

Full Thickness Loss of Skin

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tion tissue is covered by a continuous layer of new epithelium.

Wound contraction plays an important role in closing wounds where tissue has been lost and in diminishing the surface area to be epithelized. Carrel (1910) was the first to appreciate the participation of both epithelization and wound contraction in the healing of wounds; his studies of the healing of wounds with loss of tissue on the trunk of laboratory animals indicated that wound closure in these animals was effected mainly by the contraction process.

Fibrous Tissue Changes in the Slowly Healing Wound

Epithelization from the edges of a defect is a slow process; although epidermis grows at a fairly constant rate, a greater period of time is required for the epithelization of wounds when loss of skin has occurred. Prior to the completion of epithelization changes in the underlying granulations influence the course of healing (Converse, 1942); these alterations are attributed to the maturation of the collagen in the wound.

Histological sections of young granulation tissue reveal numerous newly formed blood vessels and young fibroblasts which are arranged parallel to the blood vessels; after three or four weeks, the cells in the lower layers of the granulation tissue assume a more horizontal direction, aligning themselves perpendicularly to the blood vessels. Coarser collagen fibers then appear between the fibroblasts, the latter becoming flattened and spindle-shaped as they increase in size

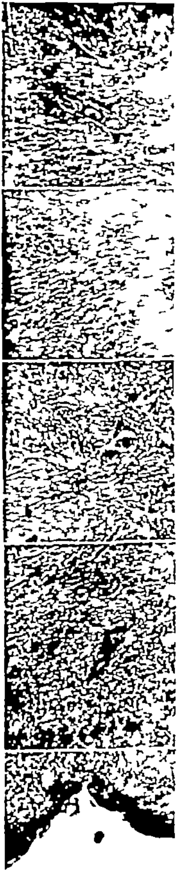

FIG. 29.

FIG. 29. Section showing fibrotic changes in a wound unhealed for four months.

A. Granulation tissue showing inflammatory changes in the superficial layer.

B. Organized granulation tissue. The fibroblasts show nuclei which have assumed a position perpendicular to the blood vessels.

C. Fibrous scar tissue with collagen formation and obliteration of blood vessels, in the deep layer.

(J. M. Converse, Proc. Roy. Soc. Med. 34: 791, 1941.)

(Fig 29) the deep layer of collagen grows at the expense of the superficial layer of granulations. Many capillaries are obliterated by the increasing mass of collagen the superficial layer of granulation tissue is thus deprived of a part of its blood supply The granulations appear cyanotic and edematous upon gross examination due to venous congestion Pressure dressings, applied at the first evidence of impaired circulation control much of the venous stasis, and the granulations assume a pinker and healthier appearance As the fibrous tissue encroaches upon the superficial granulation tissue the surface tends to become necrotic through defective circulation thus establishing an ideal culture medium for pathogenic organisms. The granulations should therefore be covered with a skin graft dressing in the early stages before the changes occur

Epithelization

Regeneration of epithelium proceeds at a constant rate in fresh wounds and is not influenced by the size of the wound Experimental studies in rabbits reveal that the average rate of epithelial growth is approximately 0.5 mm per day (Howes, 1943) Epithelization however may be retarded or arrested entirely by infection trauma and vascular changes in the granulation tissue. Trauma and frequent dressings may tear and loosen the thin advancing margin of epithelium. Vascular changes in the granulation tissue are due to an invasion of fibrous tissue which occurs when wounds remain non-epithelized for many weeks. The epithelial cells pile up when the epithelium has an unfavorable base and form a more differentiated epithelial border· such a process eventually results in an indolent ulcer

Wound Contraction

Contraction occurs early in the process of healing (primary or wound contraction) and continues during and after epithelization (secondary or scar contraction)

Fibrous tissue changes in wounds which remain unhealed for many weeks form a mass of scar tissue if the wound is large, infected if it remains unepithelized or has not been grafted The maturation of the collagen initiates a new contracting process leading to contracture distortion and deformity The degree of contracture is proportional to the length of time required for epithelization

It is chiefly the relationship of the skin to the underlying tissue that determines whether epithelization or contraction will predominate as the healing factor (Arey 1936) When the tissues around the wound are loosely attached to the underlying structures as in the cheeks and neck, the resulting contracture may be sufficiently severe to cause gross distortion of the facial features (Fig 30) Contraction causes the displacement of the loose tissue toward the attached tissue when the edges of the defect are firmly attached on one side and loosely fastened on the other

In contrast to the marked contraction in such wounds, Loeb (1920) noted in the ears of rabbits that closure is effected almost solely by epidermization in the healing of wounds situated on the firmly attached skin

When the wound is situated in an area where tissues are more firmly bound to the underlying structures, as in the scalp forehead or bridge of the nose, and are in an unfavorable location for contraction growth of epithelium may be either retarded or entirely arrested. An unhealed wound a frequent condition after exposure of the frontal bone results. Healing will not occur until after necrotic soft tissue and bone sequestra have been eliminated.

Intussusceptive Growth

Billingham and Medawar (1955) studied healing of skin wounds with loss of tissue in the flank of fur bearing mammals. The structure of such skin differs considerably

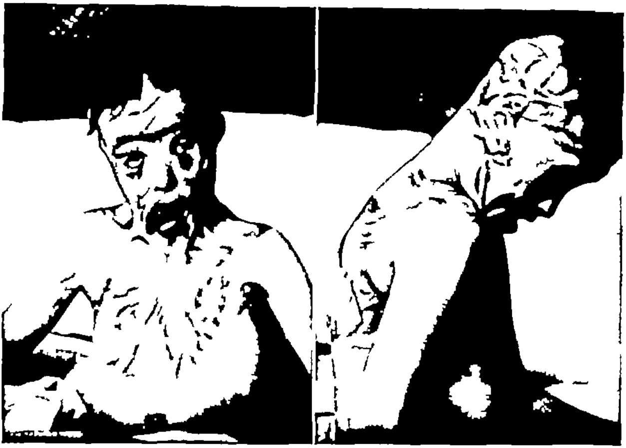

FIG 30 Distortion of the face resulting from burn contractures as a result of spontaneous healing of wounds with loss of skin

from that of man. An adipose layer the panniculus adiposus lies under the epidermis and dermis of these animals underneath this layer is a thin muscle sheet the panniculus carnosus. The main blood vessels of the skin lie within and on the surface of the panniculus carnosus, a loose cellular layer of areolar tissue separating the panniculus carnosus from the underlying musculature A wound with a large skin defect in such animals heals essentially by contraction resulting in a linear scar In one of their experiments, Billingham and Medawar left an island of skin in the center of the wound this area of skin increased in size after healing The extra dimension was produced by a stretching of the skin and enlargement of the cells, a process which they termed intussusceptive" or interealary" growth the hair follicles, for example were found to be further apart in the wound after healing was completed

Healing by maximal contraction and intercalary growth is also seen in man in areas such as the thigh abdomen and the loose soft tissues of the face.

The Vicious Cycle of the Unhealed Wound

Fibrous tissue develops when skin loss is extensive circulation is impaired and infection of the wound occurs epithelial growth is retarded and additional fibrous tissue is deposited. This cycle repeats itself indefinitely and the wound remains unhealed. Covering of the wound by a graft is necessary to avoid an unhealed wound with ensuing contractures and deformities. Early replacement of skin by grafting is imperative when loss of skin occurs.

Surface Scars

When epithelization has been slow and the healing process laborious the scarred

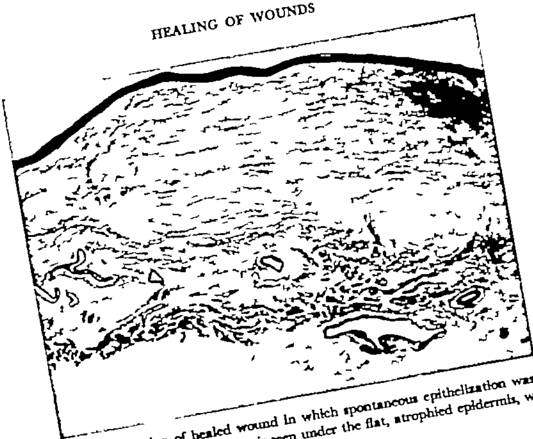

FIG. 31 Surface scar Section of healed wound in which spontaneous epithelization was prolonged over nine weeks. Dense avascular collagenous tissue is seen under the flat, atrophied epidermis, which is devoid of normal wavy papillary rete peg formation

area appears scaly stiff and dry The epithelium consists of flattened cells with a thick, heavily desquamative layer of corneum. The junction between the epithelium and the dermis is straightened and does not present the usual rete pegs (Fig 31) Dermo-epidermal separation may occur as a result of trauma The stiffness of the scar is accounted for by collagen disposed in horizontal coarse layers. Dryness is due to the absence of sebaceous and sweat glands Hair follicles are usually absent an occasional imprisoned hair follicle may be surrounded by a zone of inflammation

Partial Thickness Loss of Skin

The healing of cutaneous or dermal wounds, such as those seen in abrasions or following the removal of skin grafts of intermediate thickness resembles that of superficial burns. The epidermis and a variable portion of the dermis are destroyed in all of these wounds.

The healing of biopsied skin graft donor areas has been studied histologically (Converse and Robb-Smith 1944) Some of the findings in this study are

1 The quality of repair is approximately proportional to the rapidity of healing if healing occurs within six to ten days only a pink area remains this pales rapidly leaving a faintly visible scar with a soft pliable base. Healing within a period of fourteen to twenty-one days results in a visible uneven scar with a harder base Some donor areas remain unhealed over a three-week period and may leave contracted hypertrophic scars.

2 Rapidity of healing depends upon several factors

A. *The thickness of the graft* After removal of thin Thiersch grafts as indicated at about level *AB* in Figure 32 healing occurs within six to ten days. Donor areas of intermediate grafts taken at about level *CD* usually heal within fourteen days. When grafts are cut along level *EF* toward the base of the dermis or along level *GH*, at which lobes of fat begin to appear healing is a slower process, requiring from twenty-one to fifty-eight days.

B *Thickness of the skin of the donor site* When grafts of identical thickness are taken with the dermatome from various donor

FIG 30. Distortion of the face resulting from burn contractures as a result of spontaneous healing of wounds with loss of skin.

from that of man. An adipose layer the panniculus adiposus lies under the epidermis and dermis of these animals underneath this layer is a thin muscle sheet the panniculus carnosus. The main blood vessels of the skin lie within and on the surface of the panniculus carnosus, a loose, cellular layer of areolar tissue separating the panniculus carnosus from the underlying musculature. A wound with a large skin defect in such animals heals essentially by contraction resulting in a linear scar In one of their experiments, Billingham and Medawar left an island of skin in the center of the wound this area of skin increased in size after healing The extra dimension was produced by a stretching of the skin and enlargement of the cells, a process which they termed intussusceptive" or intercalary" growth the hair follicles, for example were found to be further apart in the wound after healing was completed.

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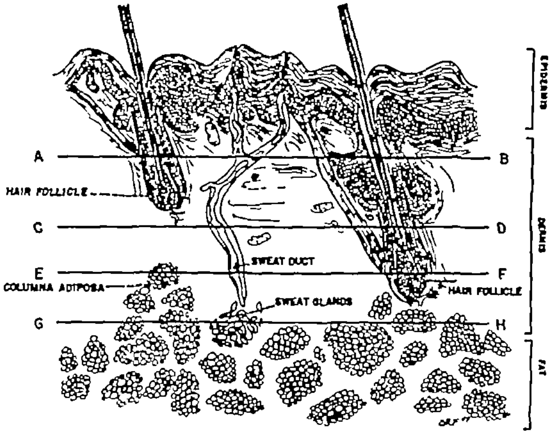


Fig 32 Diagram of skin showing levels at which skin grafts are removed
AB level of a Thiersch graft.
CD level of an intermediate or split thickness graft.
EF level of a thick graft.
GH level of a full thickness skin graft.
(Figs. 32–53 J M Converse and A. H T Robb-Smith, Ann. Surg., 120:873 1944)

areas on the abdomen where the dermis is thick, healing occurs more rapidly than in those taken from the thigh where the skin is thinner

C. *The degree of looseness of the donor skin area* Healing occurs more rapidly by contraction when skin is loosely attached to the underlying structures.

D *Presence or absence of infection* Necrosis of the remaining dermis is followed by sloughing and granulation in infected donor areas and healing occurs slowly

Wounds with complete or partial loss of skin heal similarly to other types of wounds by epithelization and contraction.

Epithelization

When a graft is taken from a donor area the epidermis is always removed with it (Fig 33) New epithelium therefore must originate from epithelial elements in the dermis, and also from the epidermis at the wound edges. Histological sections reveal that sebaceous glands and hair follicles participate in re-epithelization and are the main source of regeneration (Figs. 34–37) The epithelial elements of sweat ducts assist in supplying epithelium when thick grafts are removed the regenerative power of these ducts, however is not as great as that of remaining hair follicles, and the process of repair is much slower Full thickness regeneration of the dermis occurs when a thin skin graft is removed Unless the destruction of skin includes the reticular or deep layer of the dermis healing without a visible scar is the rule (Bishop 1915) Skin which has been removed five successive times

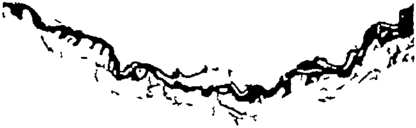


FIG 33 (*Above*) Thin graft removed from the abdomen (about 0 008 on the dermatome calibration) when fixed and embedded, showing a portion of the dermis removed HE × 20

FIG 34 (*Below*) Donor area two days after removal of a thin graft showing commencing epithelial regeneration from a hair follicle and from the sebaceous glands. HE × 40

from the same area at intervals of three weeks, not including significant depths of the reticular layer of the dermis, has regenerated to full thickness and normal texture without scarring

When a skin graft is removed through the deep or reticular layer of the dermis, the initial appearance of epithelium occurs in the region of the hair follicles (Figs. 38–40) each island of epidermis thus formed is joined to a neighboring island by the spreading epithelium The resulting scar varies from a pink soft surface with only slight change of texture to a red hypertrophic scar characteristic of donor areas from which a thick skin graft has been removed.

The hair follicles diminish in number as the deeper reticular layer of the dermis is approached for many hair follicles are implanted superficially The decrease in available epithelium is demonstrated by cutting skin grafts with the dermatome at different levels When a thin graft is cut many small bleeding points are visible these are the transversely sectioned vessels of the skin separated by areas of connective tissue which contain hair follicles. The bleeding points in thicker grafts are larger and more widely spaced the hair follicles are also more widely separated. Protrusions of fat appear near the base of the dermis because of the irregular junction of the fat with the dermis the islands of fat facilitate contraction during healing

In summary the process of epithelization is initiated in numerous islands of epithelium which tend to join each other by cellu

FIG 35 (*Top*) Donor area three days after removal of a thin graft showing the epithelial sheet spreading out from a hair follicle HE × 40

FIG 36 (*Center*) Donor area five days after removal of a thin graft Epithelial regeneration is complete the epithelium is thicker than in Figure 35. There is a suggestion of rete peg formation and loose subepidermic connective tissue can be seen, particularly at the right hand end of the section. HE × 40.

FIG 37 (Bottom) Donor area nine days after removal of a thin graft. Epithelial regeneration is complete the epithelium is much thicker than in Figure 35. There is keratinization and well-marked, though irregular rete pegs. The newly formed loose subepidermic connective tissue is shown. HE × 40

FIG 38 (*Top*) Thick graft from abdomen (about 0 032 in on dermatome calibration) when fixed and embedded, showing the removal of the dermis and of the hair follicles. HE × 20

FIG 39 (*Center*) Donor area three days after removal of a thick graft only occasional minute islands of epithelium can be seen around the sweat ducts. (Compare with Figs. 34 35 36.) HE × 40

FIG 40 (*Bottom*) Donor area five days after removal of a thick graft most of the donor area is bare and there is only a small island of epithelium arising in relation to a sweat duct. (Compare with Figs. 36 37) HE × 40.

lar multiplication and migration the number of these islands is in direct proportion to the rapidity with which healing occurs.

Sections which have been removed from rapidly healed donor areas after the removal of a thin graft reveal a good quality of epithelium over a thin layer of loose connective tissue (Fig 41) This layer is

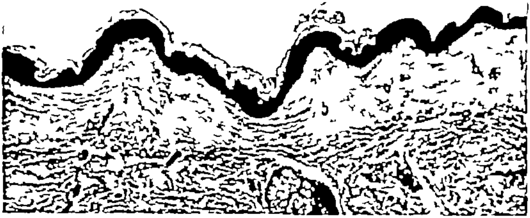


FIG. 41 Healed donor area 32 days after the removal of a thin graft. The epidermis is keratinized and of moderate thickness. Rete pegs are not marked but there is the normal undulation of the skin, and hair follicles. The contrast between the new-formed subepidermic connective tissue which is becoming collagenized and the coarse collagen fibers of the original dermis can be clearly seen (Compare with Figs. 37 and 45.) HE × 40.

FIG. 42 Normal skin showing elastic fibers. There is an imperceptible transition from the coarse fibers of the dermis to the fine fibers of the subepidermic region. Orcein × 170

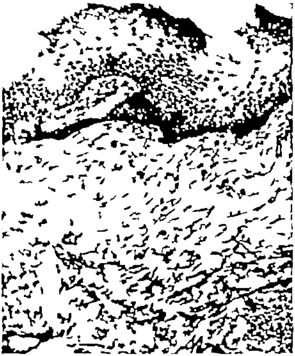
relatively avascular; elastic fibers do not develop until epithelial healing has been complete for some time (Figs. 42–44) Only very fine fibers are present even at five weeks. The appearance of the donor area differs after the removal of a thick graft when the healing process has been a slow one Under a thin atrophic epithelium little rete peg formation and few or no hair follicles are present but a thick layer of horizontally arranged collagen fibrils, completely deficient in elastica may be observed (Figs. 45 46) The entire dermis is poorly vascularized. This accounts for the hard base of the scarred areas and the tendency of the skin to fissure and ulcerate following trauma The lack of tethering of the epithelium because of the deficiency in rete pegs has been suggested as a factor in the susceptibility of the skin to trauma (Brown 1938).

Inter island Contraction

All healing wounds contract. Healing occurs principally by epithelization in dermal wounds such as donor areas of skin grafts, abraded areas, and superficial burn wounds. Contraction of the wound also occurs during healing and reduces the intervals between the many islands from which epithelium spreads to cover the wound. The degree of contraction of the dermal wound increases with the depth of the wound.

Measurements of the degree of contraction of the wound after the removal of skin grafts can be made by comparing the size of the skin on the dermatome drum with the size of the healed donor area Little contraction occurs in the donor areas unless thick grafts are removed When the grafts are thin contraction averages from two to five per cent. The percentage of contraction increases from five to ten and may exceed twenty per cent when the grafts are cut in the base of the dermis, where fat appears.

Epithelial healing is delayed and contraction is increased by infection and me



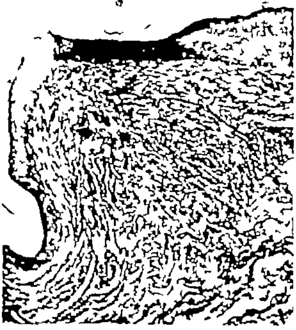


FIG 43 (*Above*) Healed donor area 12 days after removal of a thin graft from the abdomen (0 008 in. by the dermatome calibration) The elastic fibers of the original dermis can be clearly seen, but no elastic fibers have developed in the newly-formed subepidermic loose connective tissue. Orcein × 120

FIG 44 (*Below*) Healed donor area 32 days after removal of a thin graft from the abdomen (0 008 in. by the dermatome calibration) The elastic fibers of the original dermis can be clearly seen and very fine elastic fibers have developed in the newly-formed subepidermic connective tissue. (Compare with Figs. 42 and 43) *Orcein* × *120*

FIG. 45 (*Above*) Healed hypertrophic-scarred donor area 65 days after removal of a thick graft from the abdomen (about 0.034 in. by the dermatome calibration). There is a layer of atrophic epidermis with no formation of rete pegs and absence of hair follicles through sweat glands are present. The newly formed subepidermic connective tissue has become collagenized but deep to it are bundles of horizontally-arranged closely-knit collagen fibers. The original dermis can just be seen in the lower area of the photomicrograph. HT × 40

FIG. 46 (*Below*) Healed hypertrophic-scarred donor area 65 days after removal of a thick graft from the abdomen (about 0.034 in. by dermatome calibration). The elastica of the original dermis can be seen, but there is virtually no elastica in the newly-formed subepidermic connective tissue or the underlying collagen bundles. Note the thickness of the newly formed tissue (1.6 mm. 0.06 in.) whereas, in a healed donor area, after removal of a thin graft, the newly formed connective tissue is only 0.35 mm. (0.013 in.) thick. Orcein × 30 (Compare with Fig. 41)

chanical or chemical irritation. Contraction occurs more rapidly when the skin of the donor area is loosely attached to the underlying tissues. Contraction of the wound is greatest in the direction of the tension lines of the skin (Langer's lines)

Epithelial islands join their neighbors, not only by cellular division and migration but also by inter-island contraction; the *longer the period required for healing, the more marked is this contraction.* When the dermis is transected near its base, contraction in the area is apparently due to the diminution in the number of elements of available epithelium; infection and mechanical and chemical irritation produce a similar retarding effect; a thick layer of relatively avascular inelastic fibrous tissue is formed in such cases and is covered by an atrophic epithelium of poor quality (Figs. 45, 46)

The epidermis and a varying thickness of the dermis are removed in abraded areas in which sandpaper, wire brushes, or other abrasive agents have been employed. Healing then occurs similarly to that in the donor area of a skin graft or a superficial burn.

HEALING OF INFECTED WOUNDS

Contamination of Wounds

Infection and suppuration retard wound healing; the presence of pathogenic organisms in a wound, however, does not necessarily signify infection, for the wound may be merely *contaminated*; *bacterial contamination* is the rule in accidental wounds (Pulaski, Meleney and Spaeth, 1941; Altemeier and Gibbs, 1944). Positive cultures

from excised tissues reveal that contamination is due to a wide variety of organisms.

Clean incised operative wounds may be contaminated by skin organisms which exist in the deep coils of the sweat glands or in the more superficial sebaceous glands The wound may become contaminated from the air of operating rooms or hospital wards, and from oral or nasal secretions of individuals surrounding the patient. The organisms include streptococci staphylococci and clostridia welchii Facial wounds often contain mixed bacteria of the normal flora of the oral cavity The hands or respiratory tract of the surgeon nurses or assistants, or improperly sterilized instruments or bandages may be a source of wound contamination

Assuming that all wounds are contaminated infection will result when organisms find a suitable medium for development Infection may be localized spreading or generalized in accordance with the virulence of the infecting organism and the receptiveness of the wound to the development of infection.

Localized Wound Infection

Infection, when localized is limited to the wound and the adjacent tissues. Infection may result in either a small amount of exudation or marked suppuration the systemic effects are slight when the surrounding tissues set up barriers against the spread of infection. In a wound of the extremity treated under closed plaster an example of localized infection little systemic reaction occurs despite a foul-smelling, heavily suppurating wound. The effects of localized infection upon wound healing has been studied in cases treated by the closed plaster method Although the infection remained localized wound contraction occurred and connective tissue repair was active· epithelium however failed to grow It would thus seem that wound infection is detrimental to the growth of epithelium but does not impede the growth of connective tissue.

The presence of pus is detrimental to epithelial growth generally Certain organisms also seem to exert a specific inhibiting action on new epithelium this seems particularly true of various types of hemolytic streptococci for the growth of epithelium has been observed following the disappearance of the hemolytic streptococcus from superficial wounds (Colebrook and Francis, 1941) The result of more recent investigations suggest that beta hemolytic streptococci are a cause for graft failure and that granulating wounds containing such organisms should be freed of these organisms by the use of antibiotics prior to grafting (Liedberg Kuhn Barnes Reiss and Amspacher 1954) Bacillus pyocyaneus is particularly detrimental to growing epithelium Bacillus proteus is often found in wounds which contain devitalized tissue and sloughs epithelization is retarded until these dead tissues are eliminated.

Staphylococci (albus, aureus) diphtheroids, and many other organisms are found in old unhealed wounds of the face Microaerophylic streptococcus infection of the face causing dissecting ulcerating lesions, is rarely seen Infection by Vincent s organisms may complicate the healing process in wounds of the oral cavity

FACTORS INFLUENCING WOUND HEALING

General Factors

Wounds heal more rapidly in the young· the rate of healing is inversely proportional to age (Du Noüy 1916) Investigations in the rat indicate that the lag period is shorter in the young and tends to lengthen with age. Collagen deposition in the wound is initiated one day earlier in young rats as measured by tensile strength and microscopic examination The period of accelerated fibroplasia is of longer duration in the young from the third to the seventh days, in contrast to the duration in adult animals, which is restricted to the period from the

fourth to the sixth day. Carrel and Ebeling (1921) studied the effect of serum from animals of different ages on fibroblastic proliferation in tissue culture and found no stimulating factor present in the serum from young animals; there was evidence, however, of the restraining power of adult serum on cell multiplication. Carrel suggested that the inhibiting factor was associated with the lipoid fraction.

The rate of healing increases with the rise in temperature of the wound (Ebeling, 1922). The increase in local temperature due to vasodilation may account for the acceleration of healing in sympathectomized areas (Leriche and Haour, 1921).

Abnormal conditions retard the healing of wounds. Although the relationship between nutrition and wound healing has not been fully delineated, a number of nutritional factors seem to influence the healing process. Höjer (1924) demonstrated that vitamin C is intimately related to the synthesis and maintenance of the intercellular supporting framework necessary for healing. Lanman and Ingalls (1937) revealed that rupture of abdominal wounds of scorbutic animals occurred at a pressure one third of that required to tear similar wounds of normal animals. Collagen was sparsely deposited in the wounds of vitamin C-deficient animals. Lund and Crandon (1941) showed that experimental wounds failed to heal when ascorbic acid disappeared from the plasma and leucocytes.

Wolfer, Farmer, Carroll and Manshardt (1947) noted that efficiency of wound healing was impaired in experimental vitamin C-deficient humans, as estimated by tensile strength measurements. When healing is poor, as in undue wound tension or diminution of blood supply, ascorbic acid depletion is even more evident through gross failure of primary wound healing. Such cases suggest a need for ascorbic acid in the tissues in order that there be maximal resistance to infection. Interest has been aroused in the abnormalities of vitamin C metabolism following acute trauma; some patients, previously well and in a good nutritional condition, were "biochemically scorbutic."

It has long been suspected that a relationship existed between the status of the body proteins and wound healing. The lag period was shortened in dogs fed a high protein diet and contraction in open wounds began almost immediately (Clark, 1919). The rate of fibroplasia was increased by a high protein intake in sutured wounds (Harvey and Howes, 1930). Wound disruption occurred in dogs fed a protein-poor diet; histological sections of the wounds showed edema and absence of healing (Thompson, Ravdin and Frank, 1938); this was attributed to the exudation of fluid into the interstitial spaces as a result of the low osmotic pressure occasioned by the low blood protein level.

Skin grafts may fail in cases of burns with full thickness loss of skin and hypoproteinemia. The lower protein level is in all probability due in large part to the amount of protein lost in the exudate from the burn surface, which in extensive burns, as determined by Co Tui, Wright, Mulholland, Barcham and Breed (1944), may reach the proportions of about 60 grams a day. To replace this amount of protein would require a daily transfusion of 1000 cc. of plasma. The observations of Mulholland, Co Tui, Wright, Vinci and Shafiroff (1943) on decubitus ulcers sheds some light on the necessity of adequate protein nutrition for wound healing and indicate that patients with decubitus ulcers suffer from hypoproteinemia; laboratory tests revealed a negative nitrogen balance. These ulcers and other concomitant wounds were indolent and flaccid with pale edematous granulations and a thin grayish exudate. After reversing the nitrogen balance from negative to positive, the wounds began to contract and become firmer, the granulations became pink, the exudate decreased, and healing was meas

urable from one day to the next (Levenson Birkhill and Waterman 1950)

The relationship of protein to wound healing was restudied by Kobak, Benditt Wissler and Steffee (1947) Protein depletion in albino rats was effected by a low protein diet for a period of three months A difference in latent periods between controls and low protein animals was demonstrated controls having a lag period of three days and low protein animals one to five days the curves, except for the difference in the lag period were parallel The lower tensile strength of wounds in protein deficient rats during the third and fifth postoperative days is apparently due to a diminution in the number of fibroblasts a decrease in the rate of maturation and general failure of the fibroblasts to organize with equal density along the lines of stress also to a delay in maturation of the reticulum into mature collagen

Wound healing in patients in a poor nutritional state is thought to be impaired Levenson Davidson Lund and Taylor (1945) studied the healing of thermal burns in humans. They reported no significant difference in the rate of sloughing of dead tissue in protein-deficient individuals as compared with non-deficients, but noted a marked delay in wound closure in the protein-deficient group granulations were often soggy edematous and friable and were absent in occasional cases. Local exudation and injection were increased Epithelization from the periphery or from pin point grafts was retarded or completely inhibited

Infections retard the healing of wounds. Cannon Wissler Woolridge and Benditt (1944) found that resistance to infection was lowered in protein deficient animals Balch (1950) on the contrary noted a capacity for producing antibodies equal or superior to that of healthy controls in severely ill nutritionally depleted patients.

A deleterious effect of dehydration on the healing of incisional wounds in rabbits, both normal and anemic was reported by Sandblom (1944) References in the literature to an adverse effect of anemia on the healing process have not been conclusively substantiated. Sandblom produced an acute anemia without hypoproteinemia in rabbits by bleeding them from the carotid artery and noted a mean reduction of 39.2 per cent in the tensile strength of healing dorsal skin incisions on the fifth postoperative day in the presence of anemia when compared to the control value Sako Kremen and Varco (1948) who established acute or chronic anemia by venisection noted a decreased tensile strength on the seventh postoperative day in the healing of abdominal incisional wounds

The Influence of the Healing of a Primary Wound Upon the Healing of a Secondary Wound

Clinical evidence has suggested that patients who have undergone repeated operations or injuries show an increased rate of repair of a subsequent wound in a remote location (Lorin Epstein 1927) Billingham and Russell (1956) have reviewed the literature on this subject.

The postulated acceleration in the healing process of wounds has been ascribed to a systemic factor a wound hormone or trephone (Carrel 1924) which is liberated by damaged or healing tissues. Early literature on this subject is reviewed by Arey (1936) Davidson (1943) and Cameron (1951) Efforts to demonstrate existence of this second wound phenomenon on an experimental basis have yielded conflicting results the subject remains controversial For example Young Fisher and Young (1941) and Engley Allgöwer and Snyder (1955) who studied the healing of cutaneous wounds in rabbits, state that the epithelial closure is more rapid in secondary than in primary wounds. Taffel Donovan and Lapinski (1950) studied the development of tensile strength in incised wounds in the gastric wall of rats following a primary wound in the skin and Sandblom and Mu

ren (1951) made accurate measurements of the tensile strength of incised wounds in rabbit's skin both groups of investigators failed to demonstrate the presence of the second wound phenomenon

Studies by Billingham and Russell (1956) and Converse and Ballantyne (1959) were made to learn whether a primary cutaneous defect has a demonstrable influence on the rate of healing by contraction of a secondary defect. In an experimental study on rabbits, a primary defect was produced in the skin of the thoracic wall after an interval a second defect of equal size was prepared on the opposite side. The negative findings in these investigations would seem to offer additional evidence against the concept of a 'wound hormone which stimulates the healing process.

Local Factors

The rate of healing is influenced by the anatomical location of the wound. In areas with a rich blood supply such as the nose or ear wounds heal rapidly Wounds contract rapidly in areas of loosely bound tissue wound contraction may be difficult in soft tissues over bone. Careful technique during an operation prevents crushing devitalization and necrosis of tissue. Restriction of the blood supply by mass ligature and tissue injury caused by strong chemicals or electrocoagulation interferes with wound healing Inadequate apposition of wound edges leaves a dead space, permitting the formation of a hematoma which must be replaced by granulation tissue before complete healing occurs.

Infection delays healing A healthy wound surrounded by healthy cells usually resists bacterial contamination but a wound containing devitalized tissue foreign bodies, or excess blood becomes a culture medium for organisms. The lag period is prolonged under conditions unfavorable for wound healing Infection is combatted in a wound which is free of devitalized tissue and foreign bodies, and is suitably immobilized.

Materials used in suturing wounds have an effect on the rate of healing and the quality of the scar Because all sutures are foreign bodies, their introduction into the tissues is followed by an inflammatory reaction which may prolong the lag period. The extent of the reaction is determined by the size and number of sutures, and also by the material employed. The type of suture material however is of less importance than the size of the material and the technique employed Less bulk is introduced into the wound when a fine suture is used. Less tissue is crushed within the loop of the suture if it is of fine caliber and is applied delicately

An adequate number of buried sutures and ligatures should be employed to ensure hemostasis and coaptation of the tissues. Suture material should be as fine and smooth as possible and remain inert in the tissues in order to produce a minimum degree of inflammation. These precautions diminish the amount of late foreign body reaction which may manifest itself in the elimination of the suture the formation of fibroblastic tissue around the buried suture material is also lessened. Exponents of catgut sutures contend that such late inconveniences do not occur but this may be accounted for by careful technique.

Local inflammation subsides and injury to growing cells is avoided when the wounded area is immobilized and elevated to promote venous drainage Pressure dressings prevent dead space hematoma and edema. Removal of foreign bodies and devitalized tissues avoidance of hematoma by careful hemostasis and pressure dressings all favor the process of wound healing Dressing materials should not macerate tissues and should permit absorption of exudate Non adherent materials are less apt to injure healing epithelium when dressings are changed. The open treatment is indicated to promote epidermal growth The theory that the application of any substance to a healing wound accelerates epitheliza

tion has not been substantiated by scientific evidence epidermis grows best in a dry and non-traumatized wound.

WOUND TREATMENT A HISTORICAL BACKGROUND

The evolution of the surgeon's approach to problems associated with the healing of wounds is described in a number of works devoted to the history of medicine. Particularly interesting are the reviews of Malgaigne (1840) and Trueta (1943)

One of the few erroneous concepts of Hippocrates (460–377 B C.) appears in his eighty-seventh aphorism that diseases not curable by iron that is by cutting with a steel instrument, are curable by fire. Progress in the treatment of wounds was retarded for many centuries because of the persistent use of cauterization which followed the wide spread acceptance of this teaching It had not been realized that the use of the cautery resulted in an increase of dead tissue in the wound Cauterization by hot iron or boiling oil became an even more intensified practice after gunpowder entered the scene of battle It was not until the middle of the sixteenth century that the error was recognized by Ambroise Paré who discarded the use of boiling oil and made a contribution to surgery no less beneficial than that of Lister three centuries later

Galen (131–201 A.D) believed that suppuration was an essential part of the healing process and that certain substances were capable of miraculous healing powers. That surgery made virtually no progress during the next fourteen centuries is largely attributable to these theories and to other fallacious conceptions. The knowledge of Greek medicine was entirely obliterated throughout Western Europe after the fall of the Roman Empire. In the East however the Byzantines the natural heirs of Greek culture preserved the great works of the Greek period Europe was enabled to study the culture and the teachings of the Greeks after the fall of the Byzantine Empire in 1453 from an original manuscript which was brought to Europe from Constantinople.

Meanwhile two important schools of medicine had been established in the West one at Salerno in southern Italy founded by the Greeks in the tenth century and the other in the eighth century at Montpellier in the south of France. The school at Salerno had inherited some of the traditions of Greek culture and was in contact with the cities of Byzantium and Toledo in Spain where Greek teaching had been preserved Relations also appear to have been established with centers of Arabian learning The leading surgeon of the Salerno school was Bishop Servia known as Theodoric (1205–1296) Theodoric opposed the doctrine of Galen and was the first to recommend the expectant treatment of wounds, known as the dry treatment.

Henri de Mondeville, of Norman origin and a lecturer at Montpellier appears to have become acquainted with the work of Theodoric in Italy He also believed that suppurating wounds should be washed clean and that nothing whatever be placed in them Unfortunately his pupil in Montpellier Guy de Chauliac (1300–1368) who was a man of great talent and personality believed in the Galenist doctrine that the surgeon must interfere in the healing of the wound. He and others of his school spent much time and ingenuity in attempting to discover some miraculous substance which would aid in the production of suppuration in order to promote healing Because of the authority and prestige of de Chauliac, his methods were adopted throughout Europe as the orthodox treatment of wounds, and surgical interference with the natural healing power of the body remained a general and widespread practice until the Renaissance.

A Swiss surgeon known as Paracelsus (1493–1541) published a book in 1528 dealing with the treatment of wounds in which he observed that it is nature's own medicine and not the surgeon's interference that heals

wounds. Progress was being made in the field of anatomy and physiology The teaching of Vesalius (1514–1564) in Padua and Paris and the publication of his book *De Fabrica Humani Corporis* (1543) in which he confuted anatomy as taught by Galen, gave surgeons a better knowledge and a more sound basis for the logical treatment of wounds.

The steady growth in knowledge of human anatomy and physiology had far reaching results, for physicians began to disregard philosophical theories and to investigate the facts for themselves this era produced the first two great surgeons of modern times Ambroise Paré and Leonardo Botallo. Ambroise Paré (1509–1590) discarded the use of boiling oil as a method of treating wounds, placing confidence in the healing power of nature which he epitomized in the well known saying, Je le pansay Dieu le Guarit (1575) The following quotation is from Johnson's translation (1634) of Paré's book I observed and saw that all of them used that Method of dressing which Vigo prescribes and that they filled as full as they could the wounds made by Gunshot with Tents and pledgets dipped in this scalding Oyle at the first dressings which encouraged me to do the like to those, who came to be dressed of me. It chanced on a time that by reason of the multitude that were hurt I wanted this Oyle Now because there were some few left to be dressed, I was forced that I might seeme to want nothing and that I might not leave them undrest to apply a digestive made of the yolke of an egg oyle of Roses, and Turpentine. I could not sleep all that night for I was troubled in minde and the dressing of the precedent day (which I judged unfit) troubled my thoughts and I feared that the next day I should find them dead or at the point of death by the poyson of the wound, whom I had not dressed with the scalding oyle Therefore I rose early in the morning I visited my patients, and beyound expectation I found that such as I dressed with a digestive onely free from vehemencie of paine to have had good rest and that their wounds were not inflamed, nor tumifyed but on the contrary the others that were burnt with the scalding oyle were feaverish tormented with much paine and the parts about their wounds were swolne. When I had many times tryed this in divers others, I thought thus much that neither I nor any other should ever cauterize any wounded with Gunshot.

Leonardo Botallo served in the French Army and went to Paris in 1561 where he won favor with the royal family and particularly with Catherine de Medici He investigated the various ingredients of gunpowder and demonstrated that it contained nothing poisonous. He therefore concluded that the poisoning of gunshot wounds was not due to the powder but the presence of foreign bodies, not only materials introduced from without but also fragments of bone contused and lacerated tissue and clots of blood He was convinced that these must all be removed and the affected area restored to a normal condition

The intellectual ferment that characterized the Renaissance gradually passed away and was followed by an era of stagnation. In some countries, the prestige of the surgeon fell so low that he was subjected to inconceivable indignities, a typical example being the flogging to which the Prussian surgeons of Frederick the Great were submitted when soldiers of his guard died of wounds.

England did not experience the decline which followed the Renaissance On the contrary it was in this period that William Harvey (1578–1657) made his classical contribution to the progress of medical science by his description of the circulation of blood based on direct observation and experiment a revolutionary method of approach which also characterized the work of John Hunter (1728–1793) a century and a half later Hunter described shock and inflammation and the important role played

by the lymphatic system in the absorption of foreign material from the tissues.

Pierre Desault (1744–1795) initiated the modern treatment of war wounds. He was the first surgeon to adopt the technique of debridement which he taught to Larrey and other students. Desault described debridement" as a deep incision made for the purpose of exploring and draining the wound and exposing damaged structures Desault was in charge of surgery at the Hotel Dieu in 1785 and gained much experience in the treatment of war wounds during the French Revolution His technique of initial debridement was widely adopted and led to an immediate improvement in results. One of Desault's greatest contributions was his insistence on the importance of excising dead tissues in addition to simple debridement. Larrey gives many examples of the need for the excision of dead tissue in wounds. Dominique Larrey (1766–1842) was a skilled technician a great organizer a hard worker and a man of complete sincerity and modesty He accompanied Napoleon Bonaparte in all his campaigns these he recounts in his Mémoires de Chirurgie Militaire (1812–1817) One of his great contributions was his insistence on the importance of early treatment. He was convinced that the prognosis depended largely on the interval between injury and surgical assistance. He developed an ambulance service in order to reduce the time lapse and to bring hospital facilities within closer reach. The ambulances were called "ambulances volantes (flying ambulances) to illustrate the rapidity with which they reached the wounded.

One of the outstanding surgeons of the Crimean War was Nicolai Pirogoff (1810–1888) who was in charge of the treatment of Russian troops during the siege of Sebastopol He was a firm believer in the importance of early surgical treatment and was one of the first to adopt the more recent advantages of surgery such as plaster of Paris bandages and ether anesthesia only a few months after it was first advocated by the Boston surgeon Bigelow in 1847

Louis Ollier (1825–1900) believed that absolute rest was of great value in the healing of wounds and introduced a technique of completely immobilizing the limb in a plaster of Paris cast which he called the occlusive technique this was the first application of the principle of rest in its best form Ollier was the first surgeon who stressed the importance of immobilizing the wounded part, later re-emphasized by Winnett Orr and Trueta

The field of operative treatment was quickly enlarged following the discoveries of Pasteur the introduction of antiseptic technique by Lister in 1867 and the teachings of William Stewart Halsted (1852–1922) who called attention to the need for gentle handling of tissues and thorough hemostasis. Wound debridement and excision of devitalized tissues as taught by Desault and Larrey attained new importance during World War I Alexis Carrel (Carrel Dakin Daufresne Dehelly and Dumas, 1915) in an attempt to reduce the number of infective complications that followed either incomplete or incorrectly applied surgical treatment introduced the use of sodium hypochlorite a solution prepared by Dakin He laid the foundations of the technique of irrigation in a field ambulance at Compiegne. It is probable however that the efficiency of hypochlorite was not due to its bacteriocidal action but to its proteolytic capacity its lack of toxicity to the tissues and to the fact that continuous irrigation involved little interference with the natural healing process.

Winnett Orr toward the end of World War I observed that soldiers admitted to his hospital with wounds enclosed in a plaster cast to facilitate their transport to the United States were generally in a better condition than those who had been treated by the orthodox methods of the time despite the bacterial infection present in all of these wounds, granulation was proceed

ing undisturbed and the patients showed no clinical signs of sepsis. This observation led him after the war to develop a technique for treating infections of the extremities, and osteomyelitis in particular by providing drainage and complete immobilization of the limb in plaster

Trueta (1910) and other Spanish surgeons adapted Orr's closed plaster treatment for osteomyelitis during the Spanish Civil War The wounds were immobilized under a mild degree of pressure by the plaster encasement. One of Trueta's most important contributions was his re-emphasis of the necessity for early removal of devitalized tissue previously stressed after the war of 1914-1918

Immobilization of the wound under firm bandage pressure was advocated principally by Koch (1938) the dressings being removed periodically and the wound cleansed. Pressure over the wound encouraged venous return from the wounded area and diminished local edema

A method frequently advocated in the past for the treatment of superficial wounds and burns was reintroduced by Wallace in 1919 He noted the rapid healing of superficially burned areas in children when these were left exposed to the air He began employing the method when numerous changes of dressings became impractical because of lack of adequate trained personnel It was then observed that burn wounds without dressings healed rapidly patients also suffered less pain and fewer systemic reactions than those treated under pressure dressings.

The Open versus Closed Treatment of Wounds

Observations of the healing of deep wounds involving bone such as compound fractures of the extremities immobilized in plaster show that infection is controlled that less systemic repercussion from the suppurating wound occurs and that connective tissue repair proceeds at a rapid rate Epithelial healing however is slow under plaster Epithelium requires a dry medium for growth the presence of pus is an interference. Epithelium develops best under a dry crust in the absence of moisture. Organisms such as bacillus pyocyaneus thrive in a moist and suppurating wound but tend to disappear when the wound is dried. Drying the surface in the treatment of infected donor areas of skin grafts is effective. The wound is exposed to a current of warm dry air from an elecric hair dryer after a number of treatments the oozing surface becomes covered with a crust under which healing occurs rapidly

The open method of treatment is particularly satisfactory for facial wounds because of the difficulty of applying pressure dressings over the entire face. Closed pressure dressing or exposure of the wound area to the air are methods from which to choose in the treatment of wounds of the face the choice depending on the proper application of the selected treatment. A pressure dressing is always useful in a freshly sutured wound because pressure tends to prevent postoperative edema thus controlling tension on the sutures. Compression enhances circulation in the area by preventing edema and supporting venous flow The healing wound is also immobilized by the pressure dressing Open treatment is indicated in superficial burns and in abrasions where a dry surface is required for the growth of epithelium If oozing occurs in the superficial wound the use of the hair dryer insures the formation of a natural crust under which epithelization occurs. Pressure dressings promote the growth of healthy granulation tissue previous to the application of a skin graft. Some granulating areas appear dirty and sluggish when left open. A pressure dressing enhances circulation by reducing edema and favors venous return in the granulation tissue dirty cyanotic granulations take on a bright cherry red color a wound surface that calls for a skin graft Pressure dressings are also useful in suppurating wounds particularly in

compound fractures involving the mandible. Immobilization and pressure over the soft tissues combined with fixation of the fractured bone fragments favor control of infection and also act as essential aids to other measures such as removal of devitalized tissues, foreign bodies and effectiveness of antibiotics. Alternate use of open and closed methods is indicated in some cases. A facial burn for example may be treated by the open method until the sloughs of deeply burned areas are removed and epithelization of the superficially burned areas is obtained pressure dressings can then be employed to prepare unepithelized granulating areas for skin grafting

Enzyme Therapy of Wounds by Streptokinase-Streptodornase

Streptokinase and streptodornase are enzymes, each of a special type, produced by hemolytic streptococci when grown in a bacterial culture medium (Tillett and Garner 1933 Tillett Sherry and Christensen 1948[1] 1948[2] Tillett and Sherry 1949) The preparations used for therapeutic purposes have been highly concentrated and purified from the growth of large quantities of the organisms in a fluid medium Entirely separated from the bacterial cells, these enzymes prepared and supplied under the trade name of Varidase (McCarty and Tillett 1952) exist together in a dried sterile powder are readily soluble in water or physiological salt solution and are capable of potent enzymatic activities.

Streptokinase causes rapid lysis of solid clots and coagula of human blood. As a therapeutic reagent when massive extravascular bleeding or excessive fibrinous exudation occurs as the result of trauma the lysis of solid fibrin affords a means of rapidly removing the solid coagula that often serve as deterrents to recovery either by aspiration or drainage.

Streptodornase is the technical chemical name for desoxyribonuclease and acts specifically on a desoxyribose nucleoprotein. This particular nucleoprotein constitutes almost seventy per cent of the solid sediment of purulent exudates it is derived from the nuclei of cells, broken down locally by disintegration or disease. It is this nucleoprotein that gives purulent exudates the thick, viscous, stringy coarse qualities that are characteristic of pus. Streptodornase through potent enzymatic action causes a rapid and marked thinning of pus which enables the removal of exudative materials of infectional origin so often associated with the refractory nature of suppurative diseases.

Streptokinase is particularly valuable to rapidly disintegrate organized hematoma when used in injections or through continuous irrigation by means of a tube placed in the mass. Large hematomas in the face may collect from the looseness of the tissues in areas such as the cheek, streptokinase is useful for rapid lysing of the blood clots.

Streptodornase is employed in marked suppuration to cleanse the wound rapidly or to eliminate suppuration in deeply situated pockets A number of rules must be followed to obtain the maximum effect from these enzymes. Direct and sustained contact must be made between the enzymatic solution and the entire diseased area it may be necessary to open a route of entry or to employ catheters in order to introduce the solution or the enzyme may be introduced by injecting a needle into the hematoma mass or into the maxillary sinus through the lateral wall of the nose.

Thorough aspiration or drainage is required following the process of thinning by liquefaction. Aspiration or drainage is no less an obligatory requirement than is the factor of free contact of the enzyme with the diseased area. For example after hematoma has been liquified it is necesary to aspirate the liquid from the hematoma pocket. The action of the enzyme begins immediately after its introduction but is always self terminating Repeated treatments are necessary in order to renew con

tact between the enzyme and the tissues repeated instillations of the enzyme and drainage are therefore indicated.

Treatment of Wounds with Partial Thickness Loss of Skin

The wound must be placed under conditions favoring rapid epithelization in partial thickness loss of skin such as superficial burns donor areas of skin grafts and traumatic or operative abrasions. Wounds that become moist as a result of an accumulation of exudate particularly when this exudate becomes infected result in a retardation of epithelial growth. Protective dressings may permit the accumulation of exudate if the dressings are not properly anchored constant rubbing of the dressing against the healing area causes mechanical irritation which retards epithelization Such a wound when exposed to the air becomes covered by a dry crust formed by the coagulation of the covering exudate. A new epithelized area grows across the wound and the crust falls spontaneously The open method may be applied to all areas of partial thickness loss of skin

Treatment of Wounds with Full Thickness Loss of Skin

The wound with full thickness loss of skin should be treated by replacement of skin at the earliest opportunity skin should be grafted immediately whenever feasible A skin graft in the initial stages may not be possible in deep wounds involving bone with considerable tissue destruction In such instances it is necessary to institute proper treatment of the wound by immobilization, pressure and control of infection and then to await the passing of a number of weeks until the growth of connective tissue forms a *layer of granulations upon which* a skin graft can be applied. Where bone has been exposed it may be necessary to rotate a flap of full thickness skin and subcutaneous tissue from an adjacent area to cover the exposed bone.

Principles of Treatment of Facial Wounds

Treatment of facial wounds is similar to that of other wounds of the body the techniques, however vary with the location of the wound.

1 All devitalized tissue sloughs and non vital isolated bone fragments should be removed as early as possible Frequent irrigations are necessary to remove debris, devitalized tissue, bone fragments and food when there is communication between a facial wound and the oral cavity

2. The wound should be immobilized by a bandage and a firmly anchored dressing by splints, molds or other supports.

3 Wounds should be closed by primary or late primary suture wounds with loss of tissue should be covered by a skin graft dressing or closed by a pedicled flap from an adjacent area after suppuration is controlled for it is only after the wound is closed that it is devoid of bacterial contamination and infection

4 Antibiotics are essential in the treatment of infected wounds.

3

GENERAL PRINCIPLES OF OPERATING TECHNIQUE

Gentleness, patience and technical skill must be exercised in all branches of surgery. Attention to minute detail is especially essential in plastic surgery of the face for the results of such surgery are always visible.

Care in making the incisions, painstaking hemostasis, avoidance of tissue trauma and meticulous wound suture emphasize the delicacy of technique so essential in preventing infection and fibrosis. Tissues which have been devitalized by trauma become fertile soil for the multiplication of infective organisms; poor healing, wound disunion, fibrosis *and hypertrophic scars mar* the result of operation. The surgeon's awareness of the tissues as they appear under the eye of the microscope is of great assistance in emphasizing the need for careful handling of the gross structures.

Instruments

The use of precise instruments such as fine, well adjusted tissue forceps (Fig. 47) and fine hooks (Fig. 48) are necessary for handling skin edges, skin flaps and skin grafts. Sharp-cutting needles require well balanced needle holders (Fig. 49).

Sharp incision and dissection help to minimize tissue trauma. A fairly high standard of sharpness is found in detachable knife blades (Fig. 50); the blades should not be used more than once or twice. Sharp scissors are of particular importance for dull instruments tend to crush rather than to section the tissues. The blades of the dermatome and skin graft knives should be stropped before each operation and reground when indicated; sharp detachable blades, easily dispensed with, are available.

Preoperative Procedures

Preoperative medication is an important step toward the successful completion of the operation. The patient must be adequately sedated before anesthesia is initiated in order that apprehension and fear are eliminated. When the patient is apprehensive *induction of the anesthesia can be initiated* in the patient's room in the presence of the family. This procedure minimizes fear and avoids the need for forcible restraint. When local anesthesia is employed, preliminary sedation by a barbiturate and a sedative is essential. The patient should be kept quiet and calm until operation.

It is particularly necessary to avoid disturbing the patient previous to operation under local anesthesia. Under ideal conditions the patient is drowsy and relaxed when he enters the operating room. It is best to admit the patient to the hospital the night before the operation and to insure sleep by means of a barbiturate. Approximately two hours before the time set for the operation a barbiturate such as Nembutal (100 to 200 mg) is administered. Barbiturates not only induce a state of drowsiness

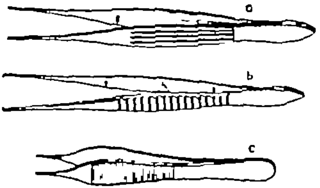


Fig 47 Examples of fine tipped tissue and thumb forceps.

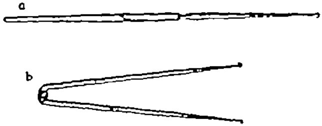


Fig 48. Fine hooks for delicate tissue handling
(a) single hook.
(b) hinged double hook

but tend to eliminate the fear of the operation One-half hour before the patient is brought into the operating room a drug such as morphine can be given hypodermically In recent years we have used Demerol (100 mg) or Pantopon (10 to 15 mg) in preference to morphine because the analgesic effect appears to equal that of morphine with less tendency to produce nausea a cause of disturbance to both patient and surgeon An additional dose of Demerol (100 mg) can be given during the operation if the amount of preoperative analgesic is inadequate The addition of adequate doses of the recently developed tranquilizing drugs appears to improve the preparation of the patient for local anesthesia

Preparation of the Skin

The skin of the face and donor areas for skin grafts are thoroughly cleansed before the patient is transferred to the operating room Gentle scrubbing with soap and water removes epidermal scales. In men the beard should be closely shaved

Elaborate measures to sterilize the skin are unnecessary Sterilization of the skin surface by an antiseptic cannot be achieved because of sebaceous glands, sweat ducts and glands in which organisms can lodge. The bacterial flora of the skin is reduced by the use of a soap or detergent Gentle handling of tissues avoids devitalization careful hemostasis prevents hematoma Tissue devitalization and hematoma favor the multiplication of pathogenic organisms in the wound.

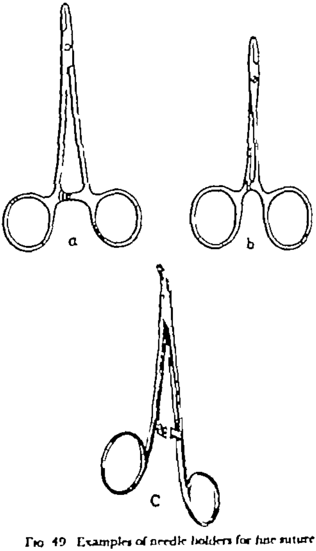


Fig 49 Examples of needle holders for fine suture needles.

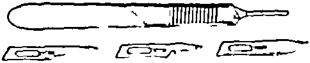


Fig 50 Knife handle with detachable blades, sizes 11 15 and 10

Before draping the field of operation the skin is painted with a colorless antiseptic solution such as aqueous Zaphiran which does not result in the stinging sensation in the eyes produced by alcoholic solutions. In operations under general anesthesia mineral oil is dropped into each palpebral fissure to protect the cornea from irritation and drying

Position

The patient lies flat on the operating table the position of the head depends on the type of operation. The horizontal position is employed in most operations.

Bleeding can be reduced considerably in the course of an operation by adequate positioning of the face If the table is inclined so that the feet are lower than the head bleeding is reduced due to the accumulation of a proportion of the blood volume in the lower extremities and trunk.

The Rose position of hyperextension of the neck is used in operations upon the upper jaw and palate. The head is slightly elevated for intranasal operations. For operations in the temporal parietal and lateral submaxillary regions the head is turned toward the unaffected side A head sheet is prepared by placing a towel over a half sheet the half sheet is passed under the head and the towel is wrapped around the head. The face is then draped with the towels, permitting exposure of the operative site. The intratracheal tube for anesthesia, passed through the nose or mouth is also draped the remainder of the body is then covered

Operative Procedures

The Incision

The creases, folds and lines of expression of the face should be carefully examined in order that the incision does not cross these lines, when possible. The incision through the skin and subcutaneous tissues must be clean direct, and must *penetrate the entire*

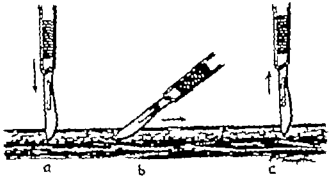


FIG 51 In order to incise at the same depth along the whole of the line of incision, the knife should be placed vertically at the beginning and at the end of the incision.

thickness of the skin at one stroke at an even depth along its entire length To accomplish this the knife should be directed vertically at the beginning and at the end of the incision (Fig 51) Incisions should be made at right angles to the surface of the skin in order that the skin edges meet in correct apposition when sutured. An oblique incision is occasionally made through hair bearing areas such as the eyebrows and the scalp. The oblique incision is made *parallel with the hair follicles since cutting* across the follicles results in a hairless scar particularly disfiguring in the eyebrow

Tension

Wound edges should be approximated without tension After scar excision the wound can often be sutured without tension In areas where the surrounding tissues are loosely attached as in the cheeks, it is not necessary to undermine the wound edges When a wound cannot be approximated without tension undermining relieves the tightness of the wound edges.

An essential principle in the designing of flaps is the avoidance of tension The edge of the flap should be sutured to the edges of the defect without tension to avoid inadequate healing with a breakdown of the suture line. In raising a flap the fat layer must be separated from the deep fascia by sharp dissection Shifting of a local flap is indicated when the wound edges cannot be brought together without tension The suc

cess of most plastic surgery operations whether the simple approximation of a wound or the shifting of skin flaps, is largely dependent upon the avoidance of tension

Sutures should be tied just tightly enough to approximate the wound edges. Tight sutures tend to produce an overlapping of the edges the ring of tissue compressed within the suture loop may undergo necrosis, a tight suture cuts through the skin surface leaving a permanent stitch mark.

Foreign Bodies

Foreign bodies in the wound may cause an inflammatory reaction and in many cases tend to be eliminated. Extraneous foreign bodies incurred at the time of an accident, such as bits of clothing earth or gravel should be eliminated at the time of the initial treatment. Foreign bodies introduced at the time of operation include suture material and also tissue crushed by pressure of a hemostat or ligature.

When buried sutures are placed close to the skin margin the sutures should be inverted the knots facing downward into the wound.

Silk cotton and catgut are well tolerated in the tissues. Nylon should not be used as a deep suture because it requires three knots to prevent unraveling and results in a larger amount of suture material being placed in the wound Stainless steel sutures may cause pricking sensations when buried Catgut becomes liquified and larger sizes are therefore less desirable than finer sizes. After having used various types of materials notably silk as buried suture material we have gradually reached the conclusion that *plain catgut in the fine sizes* is the best material to use in facial surgery unless the buried suture is used as an anchorage point in which case silk is preferable The advantage of catgut is that it is absorbed silk when placed close to the skin surface of a wound tends to be eliminated and may negate the result usually obtained by careful suturing of the wound.

Hemostasis

Meticulous hemostasis is essential in the course of wound suture and skin grafting Blood vessels should be clamped with fine pointed hemostats in order that only the vessel and as little as possible of the surrounding tissue is grasped Hemostasis is accomplished by ligature crushing or twisting of blood vessels, suture ligature diathermy coagulation or controlled hypotension

LIGATION Complete hemostasis is obtained by ligation The vessels are clamped with fine pointed hemostats, then tied with fine ligature material large vessels require stronger material When fine material is used the procedure is facilitated by tying the ligature with a needle holder (Fig 52)

CLAMPING THE VESSEL. Clamping the vessel usually induces hemostasis. Fine hemostats are applied to the vessels and to the areas of tissue where bleeding capillaries are present these are retained for a brief period each hemostat is then tightly clamped before it is removed in order to occlude the end of the vessel Although this method does not always insure permanent hemostasis, it avoids the introduction of foreign material and is particularly applicable in a wound which is to receive a skin graft The hemostat is reapplied and the vessel ligated if bleeding continues.

TWISTING THE VESSEL. The vessel may be twisted to control bleeding without introducing ligature material into the wound the surrounding tissue however may be devitalized and twisted unless care is exercised in this procedure (Fig 53)

SUTURE LIGATURE. Because massive tissue strangulation may occur in suture-ligation the procedure should be carefully avoided except in cases of bleeding vessels located in deep cavities, for these are otherwise impossible to grasp

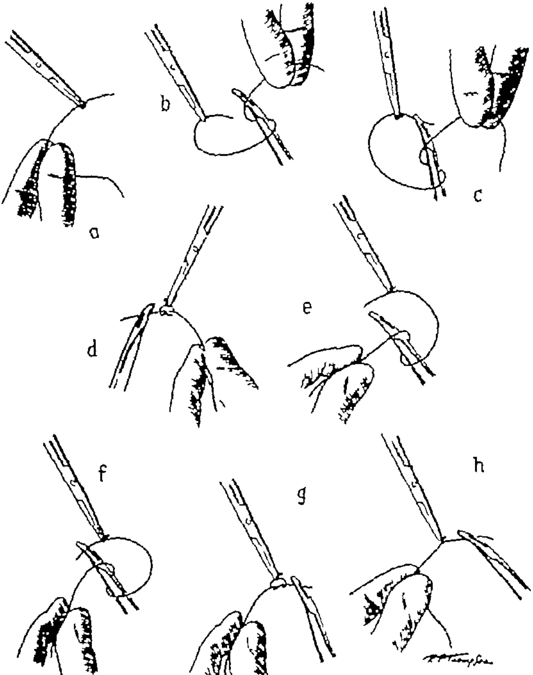


Fig 52 Exemplifying a method of tying clamped blood vessels with fine ligature material using a needle holder

DIATHERMY COAGULATION Diathermy coagulation of blood vessels reduces the operating time by avoiding the need for placing time-consuming ties and ligatures around the sectioned blood vessels. This technique presents an explosion hazard and should be used only in the absence of explosive anesthetic agents. Fine-tipped hemostats should grasp only the blood vessel and the immediate surrounding tissue. Careful regulation of the machine will insure coag

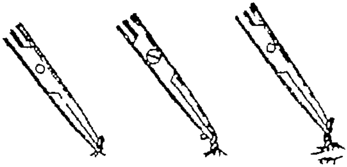


Fig 53. Arrest of bleeding by twisting a blood vessel. This procedure may cause more tissue damage than ligation unless only the vessel itself is grasped.

ulation in the blood vessel and immediate surrounding tissue only Coagulation of smaller bleeders can be accomplished by grasping them with small fine tipped forceps and applying the electrode to the forceps. Electrocoagulation should not be employed for the control of bleeding in larger sized vessels these should be ligated.

A walled off' type of coagulation without dehydrating the tissue around the coagulum as in the case of a spark gap current is obtained with electrocoagulation machines operating in the range of 85 meters radio frequency current and approximately one-third of one ampere

CONTROLLED HYPOTENSION Halsted said "We have reason to hope that the day will come when hemorrhage will be controlled by a quicker procedure than the awkward time-consuming ligature. One method for diminishing bleeding during operations is to lower the patient's blood pressure.

Under normal physiological conditions blood pressure is maintained by a finely adjusted balance between two fundamentally different mechanisms, the volume of circulating blood and the capacity of the vascular bed The production of induced hypotension is based on the disruption of one of these mechanisms. It may be either hypovolemic or normovolemic, depending upon whether the volume of the circulating blood is reduced or whether the capacity of the vascular bed is increased Normovolemic hypotension is more commonly employed for controlled hypotension

McIndoe (1956) has reviewed the development of controlled hypotension and his experience with the technique Griffiths and Gillies (1948) reduced the systolic blood pressure in malignant hypertension to attain an ischemic field for thoracodorsal splanchnicectomy by a high spinal block with procaine This induced hypotension to a systolic pressure of 60 mm of mercury or lower produced no ill effects and enabled the successful conclusion of the operation They stated that resting tissues in the human body were adequately supplied with blood for basal metabolic requirements during such induced hypotension provided that vasodilatation and full oxygenation were insured.

The introduction by Paton and Zaimis (1948) and Barlow and Ing (1948) of the lower members of the methonium series of drugs which specifically block the autonomic ganglia led Davison (1950) and Enderby and Scurr (1950) and other workers to use these drugs for lowering the blood pressure A general fall of 15 to 30 mm of mercury in the systolic blood pressure occurs when the drug is administered intravenously in the horizontal position This is not as marked a drop in blood pressure as that produced by procaine spinal infiltration By varying the posture of the patient however it is possible to pool the blood in the dilated vascular system. In this manner the blood pressure may be varied in the operative site depending upon whether the level of the operative site is above or below the heart The systolic blood pressure can be lowered by this method until it approaches 60 mm. of mercury at heart level a safe blood pressure for minimum tissue requirements The operative site must be elevated above the heart level to obtain the full benefit of this postural ischemia It is thus necessary to arrange the position of the patient on the operating table in such a way that the pooling area of the blood the heart and the operative site are in satisfactory respective positions.

The drugs of the methonium series have a number of disadvantages. Among them is the difficulty of maintaining controlled hypotension because they produce an increased pulse rate followed by an early return of normal blood pressure. Randall Peterson and Lehmann (1949) proposed a new ganglioplegic agent derived from thiophanium which they called Arfonad. This drug was administered by intravenous drip to avoid fluctuations and to achieve a steady action

Enderby (1954) reported the use of another ganglion blocking drug pentolinium tartrate known as Ansolysen which has certain advantages over other drugs there is less tachycardia and blood pressure control is consequently easier There is also a slow initial fall in blood pressure but the duration of the fall in pressure is more prolonged.

McIndoe (1956) warns that controlled hypotension must be practiced by an experienced anesthesiologist and that the control of the blood pressure is obtained for one to one and a half hours control becomes increasingly difficult after the first half hour Although a minimum hypotension of 60 mm of mercury is safe for most patients, precautions are essential The blood pressure must not fall below a minimum of 60 mm of mercury at heart level careful control must be maintained during the entire operation and a slow return of blood pressure postoperatively is necessary to limit the risk of secondary hemorrhage. Postoperative hematoma is also a frequent complication if the surgeon is not aware that the vessels that appear to be bleeding only slightly must be ligated during the operation An exact awareness of the blood pressure is essential during the entire operation and a visual type recording apparatus should be used. The method should be employed only in association with intratracheal anesthesia as full oxygenation must be assured during the entire procedure.

The routine type of operation should not be performed under controlled hypotension. The technique should be reserved for those procedures in which excessive blood loss is anticipated in cases where dissection of structures is facilitated by a dry field.

Questionnaires were sent to 602 members of the Association of Anesthetists of Great Britain and Ireland in an attempt to obtain anonymous and unbiased reports of the technique most particularly those fatal and non-fatal complications that may have resulted from its use (Hampton and Little, 1953) A mortality rate of more than 1 in 500 indicates that the technique should not be employed in the absence of a specific and urgent indication nor purely for surgical convenience. The result of the questionnaire conveyed a message of caution and restraint for the wave of enthusiasm that led to its widespread use The technique is specifically contraindicated in conditions such as asphyxia severe heart lesions, severe renal damage established shock or established hemorrhage The percentage of complications is increased in proportion to the lower levels of blood pressure obtained among the hazards listed are renal failure cerebral thrombosis and anoxia coronary thrombosis cardiac arrest and failure, and reactionary hemorrhage.

In view of the higher percentage of fatalities following the use of controlled hypotension it does not seem justifiable to employ this technique in the average plastic surgical operation in young, healthy adults. Although the perfection of the technique may eventually lead to the employment of hypotensive drugs, we feel that the main indication for controlled hypotension in head and neck surgery is in radical operations for carcinoma where considerable blood loss occurs.

CAPILLARY BLEEDING Time patience and pressure are probably the most important factors for controlling capillary bleeding Warm saline gauze packs are placed over the oozing areas these may be alternated with gauze soaked in 1 1000 adrenalin solution. Adrenalin is contraindicated in the presence of cyclopropane because of the development of cardiac arrhythmias which on occasion have been shown experimentally to progress to ventricular fibrillation. Manual pressure is applied over the packs until bleeding ceases. A local anesthetic containing a vasoconstrictor reduces the amount of bleeding The dilution of adrenalin may vary 1 cc. of 1 1000 adrenalin solution to 100 cc of procaine solution is sufficient when large quantities of the anes-

thetic are injected In nasal operations, when smaller amounts are given such as 10 to 20 cc. of procaine the dilution varies from 2 to 4 cc. of 1 1000 adrenalin solution to 100 cc of procaine solution A few moments should be permitted to pass before proceeding with the operation in order to obtain the full hemostatic effect. Local anesthesia may be used in conjunction with general anesthesia this procedure permits the anesthetist to keep the patient under light general anesthesia because no painful stimuli arise from the operative site Adequate management of general anesthesia to avoid anoxemia assists in the control of bleeding

COAGULATION ADJUVANTS. The action of thrombin in converting soluble fibrinogen into insoluble fibrin can be considered the most fundamental reaction in the coagulation of the blood (Quick 1952) Thrombin has not as yet been prepared in pure form It has been prepared from beef plasma (Seegers, Brinkhous, Smith and Warner 1938) from rabbit plasma (Lozner Mac Donald Finland and Taylor 1941) and from the leftover materials in the fractionation of human blood (Cohn 1941) bovine thrombin is the most effective of these In its clinical applications on humans, bovine thrombin has not caused sensitization and there is evidence to show that it will not do so (Light 1945).

Thrombin solution is employed as a local hemostatic agent by spraying the solution over the bleeding surface. Injecting thrombin into the blood stream should be avoided and is apt to result in embolus formation While the thrombin spray controls capillary oozing it fails to stop bleeding from minute arteries, too small to require ligation Fibrin acting as a carrier for the thrombin has proved effective

Fibrin foams are prepared from human fibrinogen and human thrombin (Ingraham and Bailey 1944) In the dry state the foams appear as dense strands of fibrin fibers and as air spaces easily seen by the naked eye. At the time of operation th bin powder is dissolved in physiolo saline solution portions of fibrin foan then placed in the thrombin solu preparatory to use

Histological studies indicate that the s pieces of foam are rapidly absorbed little tissue reaction One should a leaving large pieces in the tissues, how for these may be more slowly absorbed may also induce a degree of tissue rea in the area

Absorbable gelatin has been used substitute material for fibrin foam when latter is not readily available (Correll Wise 1945 Light and Prentice 1' Small patches of fibrin or gelatin p ously soaked in thrombin solution are plied over the bleeding areas to co bleeding

Because meticulous hemostasis is e tial before applying a skin graft to its a technique modified from that of S (1943) has been used to prepare thron and fibrinogen from the patient's bl We have obtained good results by u beef thrombin and blood bank plasma lowing hemostasis, the skin graft is ap to the area and is quite firmly fixed to bed within a short space of time by adhesive qualities of the fibrin clot.

THE ROLE OF VITAMIN K IN THE COAG TION MECHANISM OF THE BLOOD Dam Schoenheyder in 1934 discovered vita K and its role in the coagulation me nism A simplified description of the me nism of blood coagulation demonstrate action of vitamin K (Fig 54)

The antagonism between vitamin K anticoagulants, such as Dicumarol le the following theory Prothrombin

Fibrinogen Calcium Prothrombin Thrombok (Thromboplas

Fibrin — Thrombin

FIG 54 Scheme of the mechanism of coagulation

mother substance of thrombin in the liver is synthesized by an enzyme in which vitamin K functions as a prosthetic group Because vitamin K itself cannot be synthesized in the liver a deficiency of this substance results in a decrease of prothrombin production When the prothrombin level drops below 80 per cent of normal blood coagulation is disturbed or does not occur

Menadione sodium bisulfate is a water soluble form of vitamin K available in tablet form for oral administration or in ampules for intravenous parenteral use the average dose is 0.5 to 2 mg daily Preoperative vitamin K administration is also indicated in surgery of the head and neck because the postoperative diet and feeding may be limited. In patients under anticoagulant therapy who develop bleeding or an undesired fall in prothrombin level massive doses of vitamin K are required (70 to 100 mg intravenously) combined with transfusion of fresh blood.

LATE HEMOSTASIS. Immobilization of the area and application of a firm pressure dressing over the wound following the operation obliterate dead space and aid in the prevention of capillary oozing and the slow formation of a hematoma

Rest and quiet generally with the aid of sedation is necessary to avoid postoperative hemorrhage A case is recalled of a hardened soldier of the French Foreign Legion in North Africa during World War II He was operated on in the morning under local anesthesia for rotation of a skin flap on the face The patient considered the operation too insignificant to warrant remaining in bed and spent the afternoon bowling under a hot African sun. Rupture of a branch of the external maxillary artery during the night resulted in an enormous hematoma which extended from the base of the neck to the forehead closing the eye on the affected side

Absence of Dead Space

Nature abhors a vacuum the wound abhors a dead space. A dead space in a wound permits the accumulation of blood and serum, thus constituting a natural culture medium for the multiplication of bacterial organisms It is therefore necessary to approximate all the different layers when closing the wound. Should a dead space be present under the sutured skin, it may be necessary to fill the area in the subcutaneous space with a flap of adipose tissue from the surrounding tissues or a free transplant of dermis, fascia and fat (Chapter 19) Grafts of bone or cartilage are required to fill a defect involving the skeletal framework. A carefully applied pressure dressing is essential in any wound where a dead space may form

Change of Dressings

Care should be taken to avoid injury to the delicate edges of a healing wound. Removal of the dressing is a meticulous procedure for sutures may adhere to the dressing Careless handling of the dressing may pull upon the sutures or rip away a delicate crust or epithelial covering Premature or hasty removal of sutures may lead to separation of the wound edges. Sutures should be removed about the fifth or sixth day with delicate forceps and fine-pointed sharp scissors.

Some Aspects of General Anesthesia

The anesthetic risk and the volume of the anesthetic necessary to maintain anesthesia are reduced if the patient is properly premedicated Patients ranging in age from early infancy to 4 or 5 months of age have a low metabolic rate and should not be depressed with opiate or barbiturates. Only atropine or scopolamine should be given preoperatively in order to decrease reflex hyperactivity and salivary and bronchial secretions. In patients from 5 months to 3 or 4 years pentobarbital 6.5 mg per kg is given in a retention enema 40 to 60 minutes preoperatively (Stringham and Broadbent, 1956) The patient is in a state of light

hypnosis from which he may be aroused without excitement. Pentobarbital can usually be given orally in children over 5 years of age. Intratracheal intubation for infants requires special attention. They should be in the second plane of surgical anesthesia before being intubated to eliminate laryngeal spasms and subsequent trauma to the vocal cords. The average diameter of the tracheal orifice at the level of the cricoid ring in infants is 4 mm. One millimeter of edema at this level decreases the cross-sectional area to 75 per cent as compared with 19 per cent in the adult whose tracheal orifice at this same level is 20 mm (Eckenhoff 1951). The new-born infant's trachea is only 4.5 cm in length; the endotracheal tube must therefore not be inserted too far or it will enter the right main bronchus. The anesthesia should not be permitted to become light during the operation, for laryngeal reflexes cause a constant rasping of vocal cords against the intratracheal tube; this often results in severe postoperative discomfort, laryngeal edema and hoarseness. Because the size of the larynx varies in different individuals, excessively large tubes should not be used.

In complicated fractures or reconstructive operations of the mandible it is advisable to perform a preliminary tracheotomy in order to avoid obstruction of the airway by backward displacement of the base of the tongue.

Local versus General Anesthesia

Many operations about the face are performed satisfactorily under local anesthesia. When the patient is sedated adequately and is confident, bleeding is minimized, postoperative shock is eliminated and the patient returns to bed fully conscious, requiring postoperative medication only when painful stimuli appear in the operative site after the effect of the local anesthetic has disappeared.

Local anesthesia in nervous patients can be extremely troublesome for the surgeon and result in a horrifying experience for the patient. It is sometimes difficult to predict the patient's reaction to local anesthesia during an operation and the surgeon occasionally is disagreeably surprised by the lack of confidence and co-operation displayed by the patient.

For these reasons many surgeons prefer to employ general anesthesia even for relatively minor procedures in facial surgery. Controlled hypotension has been used in order to improve operating conditions and minimize hemorrhage which is always increased under general anesthetics. It would seem that an adequate appreciation of the type of patient and the type of operation being undertaken would lead to a more eclectic attitude toward the choice of these respective agents. For adults, in simple procedures about the face, we have found local anesthesia most satisfactory, combining local infiltration anesthesia with regional block anesthesia when necessary.

The use of hyaluronidase, the spreading factor of Duran Reynals, is advantageous in permitting a wide diffusion of the anesthetic. It has been used particularly in operations on the eyelids where it minimizes swelling. It has also proved useful in anesthesia for donor areas of skin grafts, as the diffusion produced by the hyaluronidase produces anesthesia of the terminal fibers in the skin and permits the cutting of the skin graft without pain.

Caution must be employed in the use of hyaluronidase, and the drug should be avoided as a routine procedure because of the danger of rapid absorption of adrenalin and novocaine into the circulatory system. Coma has been reported after the use of large quantities of novocaine combined with hyaluronidase.

Technique of Wound Suture

Wounds should be sutured layer by layer in order that all the tissues are closely approximated and no dead spaces remain. The quality of the external scar depends upon the amount of scar tissue formed

between the wound edges the more accurate the approximation of these edges, the finer the resulting scar The use of special magnifying loupes are of assistance in securing accurate apposition of the skin edges.

INTERRUPTED SKIN SUTURES. The introduction of independent sutures, each one adjusting a small portion of the skin edge secures accurate apposition Interrupted sutures may be placed a few millimeters apart if necessary and can be used to evert or invert the skin edges

EVERTING SUTURES. It is generally advisable to evert the wound edges, for eversion eliminates dead space under the suture line. The needle must be placed to form a wider loop deeper in the tissue than superficially to obtain eversion (Fig 55) the suture should be close to the wound edge at the skin surface

INVERTING SUTURES. The wound edges occasionally tend to evert excessively Inversion results when the loop is wider superficially than it is deep in the tissues (Fig 56)

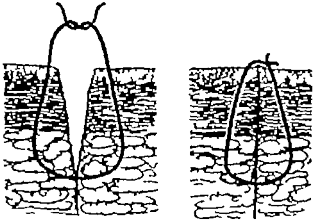


Fig 55 Correct manner of placing a suture to produce eversion

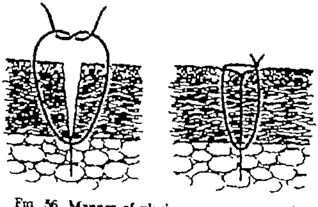


Fig 56 Manner of placing a suture to produce inversion.

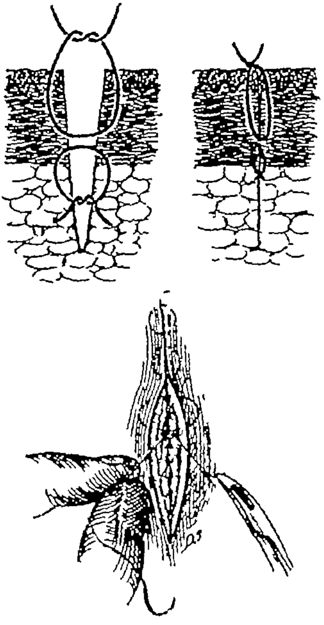


Fig 57 Intradermal sutures

(Above) Suture of the base of the dermis and superficial suture.

(Below) U-shaped horizontally placed interrupted sutures at the base of the dermis for the careful approximation of skin edges.

INTRADERMAL SUTURES. Accurate approximation of the base of the dermis must be obtained to secure a fine scar Buried sutures should be placed with the knots facing downward (Fig 57*A*) U-shaped horizontally placed intradermal sutures are often required to secure precise approximation of wound edges (Fig 57*B*)

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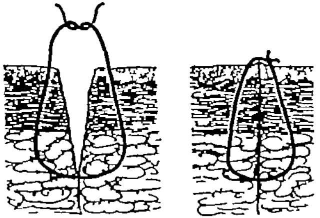

Fig 55. Correct manner of placing a suture to produce eversion.

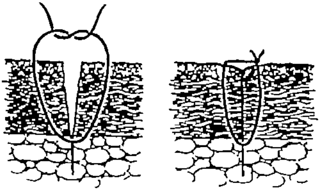

Fig 56. Manner of placing a suture to produce inversion.

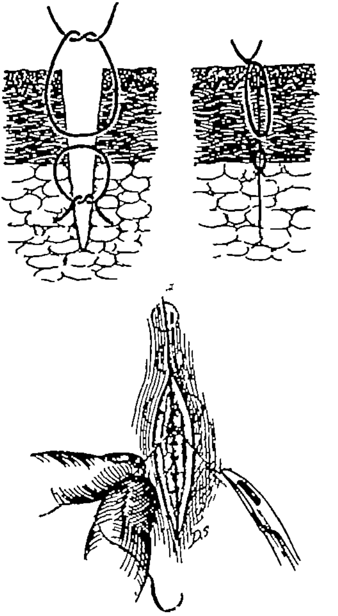

Fig 57 Intradermal sutures

(Above) Suture of the base of the dermis and superficial suture.

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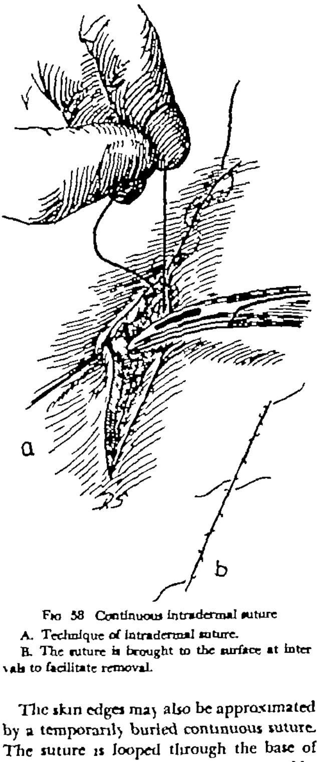


FIG 58 Continuous intradermal suture

A. Technique of intradermal suture.

B. The suture is brought to the surface at intervals to facilitate removal.

The skin edges may also be approximated by a temporarily buried continuous suture. The suture is looped through the base of the dermis, alternating from side to side and the ends are brought to the surface to permit removal (Fig 58) Close approximation can be obtained if the incision is carried through the skin at right angles and if the wound is straight.

Continuous intradermal suturing is best accomplished with a slightly resilient suture material such as fine nylon or stainless steel wire. When wire is used it is essential that an assistant hold the wire under slight tension to prevent kinking The buried suture acts as a splint, immobilizing the suture line during the healing period. The intradermal suture can be retained for a period of ten days to two weeks without causing irritation If the wound is long, the continuous suture should be brought to the surface at regular intervals in order to facilitate removal. Puckering of the wound edges occurs if the suture loops are not regularly spaced, or if they are of unequal length and of uneven depth in the dermis.

SPECIAL SUTURES. Problems arising in wound closure may require one of the following suture techniques

Mattress sutures Horizontal mattress sutures give a close approximation of the wound edges in the area of skin encircled by the suture (Fig 59*A*) Vertical or end-on mattress sutures provide eversion of the skin edges and close approximation (Fig 60). The suture shown in Figure 59*B* may be used at the junction of the scalp and skin the U-shaped intradermal suture in the skin avoids suture marks and may be retained in position a desirable feature if the wound is closed under tension

Hemostatic sutures A vertical mattress suture which incorporates the bleeding point arrests bleeding from a vessel in the skin edge The flap edges are anchored to the underlying fascia by a vertical mattress suture in order to avoid hematoma under loosely attached flaps of skin (Fig 60).

Continuous sutures The various forms of external continuous sutures save time but are often not as accurate. These sutures may be employed in areas of the body where the esthetic result is not as important as it is on the face, as for example to anchor a split skin graft to the edges of a defect to close a donor area or tubed pedicled flap. The continuous mattress lock-suture is effective in producing eversion of the wound edges (Fig 61)

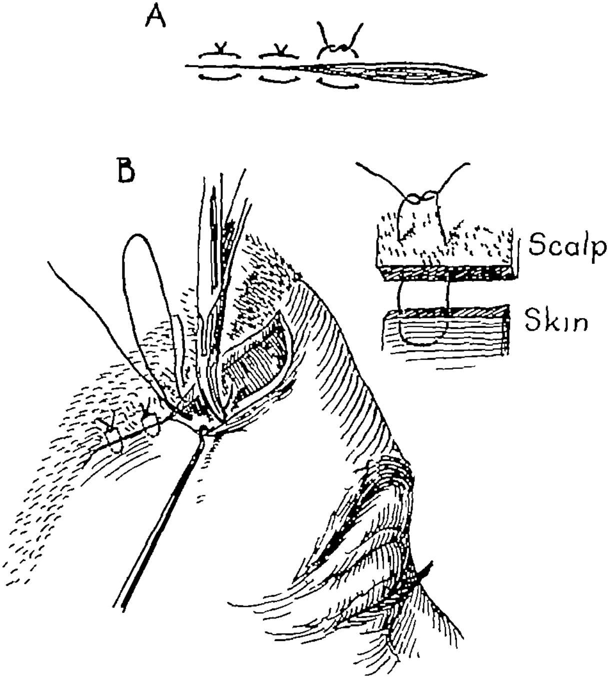


Fig 59 Horizontal mattress suture

A. Typical horizontal mattress suture.

B. Technique of mattress suture permitting the junction of the skin of the face with the scalp This technique produces an eversion of the thinner facial skin It is also useful as a traction suture as the intradermal U-shaped suture in the facial skin leaves no suture mark.

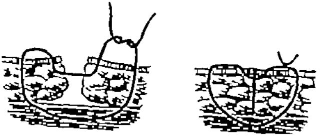


Fig 60. Vertical mattress and hemostatic suture. This suture eliminates any dead space between the fat and the deep facia

Fig 61 Continuous horizontal mattress suture

CLOSURE OF SKIN TRIANGLES. The joining of triangular skin flaps requires special care. Triangles of skin may be lost through necrosis when sutures are carelessly placed thus cutting off the blood supply to the angle

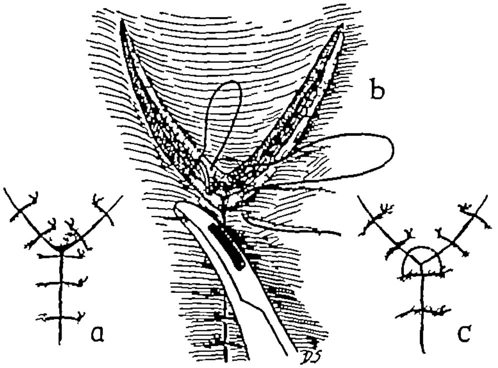


FIG. 62 Closure of a triangle
A. Necrosis of the angle caused by cutting off the blood supply by tight sutures (see dotted area)
B. Technique of intradermal triangular sutures.
C. *The triangle is closed without interference to the blood supply of the angle.*

FIG 63 Sutures for closing triangular wounds

(Fig 62*A*). An intradermal suture should be placed through the angle to avoid this danger (Fig 62*B* *C*) Other methods may be employed to close triangles without endangering the blood supply (Fig 63)

SUTURING WOUND EDGES OF UNEQUAL THICKNESS. When the wound edges vary in thickness various methods are used to shift subcutaneous tissue from under the thick edge to bolster the thin edge of the wound in order to achieve an even skin approximation (Fig 61)

Depuckering the End of the Suture Line

Due to an inequality in the length of the wound margins a pucker frequently remains at the end of a suture line the technique for resecting the excess tissue is shown in Figure 65

Breaking up the Straight Line Z plasty Stepping and Halving

The maturation of the collagen in a healing wound causes contraction In the linear scar the contraction occurs in the direction of the scar As the result of this contraction defects are noted particularly along the borders of the eyelids, nostrils, lips and ears. Notching and distortion of these structures are caused not only by improper initial sutures but by retraction of the scar following healing An effort should be made to avoid suturing the wounds along a straight line in the initial treatment of these wounds. The straight line is broken by overlapping the different layers of tissue to avoid the superimposition of layers of scar tissue thus distributing the pull of the scar tissue in different planes and opposing directions. A choice of three methods may be employed to achieve this objective

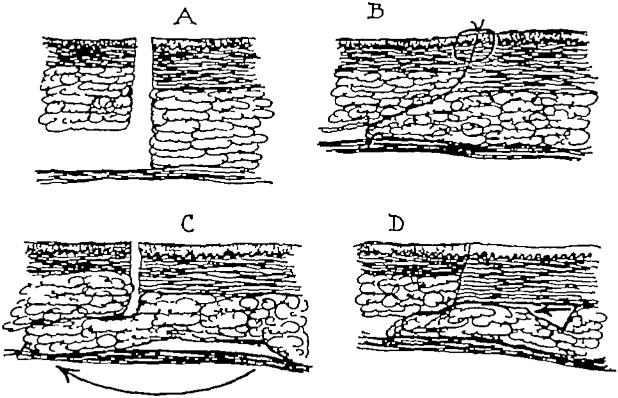
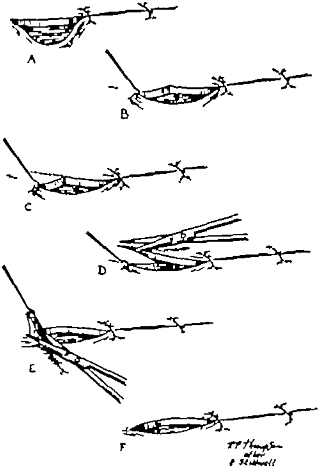


FIG 64 A and B. Suture of flaps of unequal thickness. The dead space below the thinner flap may be partially closed by advancing the adipose tissue from below the thicker flap

C. Illustrates a technique consisting in mobilizing a reversed flap of adipose tissue into the space beneath the thinner flap

D Another technique for facilitating the advancement of the adipose tissue from beneath the thicker flap The adipose tissue is separated from the dermis and partly incised This procedure permits further advancement under the thinner flap.



the z plasty the stepping and the halving techniques (Figs. 66 67)

Minor defects following the primary suture of facial wounds occur particularly in the free borders of the eyelids, nostrils, lips and ears. An effort should be made to avoid suturing the wound edges along a straight line Overlapping of the different layers of tissue to avoid superimposition of the layers of scar tissue, and breaking the line of incision distribute the pull of the scar tissue in different planes and in opposing directions. To achieve this, the broken line (Fig 66) or the halving and stepping procedures are employed (Fig 67)

Careful suturing of mucosal lacerations is essential in order to avoid stenosis or distortion in through and through wounds of the eyelids, nose, lips or corners of the mouth.

FIG 65 Technique of depuckering the end of a suture line.

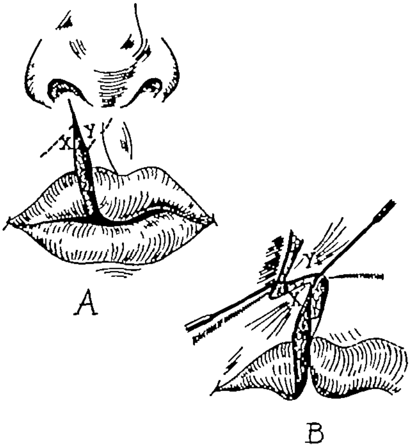


FIG 66 Technique of breaking a straight line
A. Outline of primary excision of the wound edges two small lateral incisions are made (X and Y)
B. Closure of the wound by the broken line method.

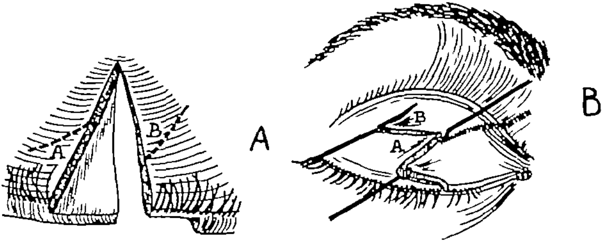


FIG 67 Eyelid suture Halving and broken line method to prevent notching (Wheeler 1922)

THE EYELIDS. The eyelids should be sutured layer by layer The first suture should always be made at the free margin of the lid to obtain continuity of the lid border the conjunctiva is then repaired with fine suture material The lids are brought together by one or two fine sutures and the skin is approximated. Tension must be distributed in different directions and over different planes because scars tend to cause contraction along the line of suture with resultant notching of the eyelid margin (Fig 67)

Partial tarsorraphy is advisable in ex

tensive lacerations, particularly when the lower lid is involved. Notching of the eyelid margin is nearly always due to the pull of a linear scar or to deficiency of conjunctiva. Even when slight deficiency of conjunctiva is apparent, a small flap may be transposed from the unaffected lid previous to tarsorraphy

THE NOSE. Lacerations of the nose should be sutured layer by layer the vestibular lining first, then the cartilage and finally the skin.

THE LIPS. The adjustment of the mucocutaneous border to avoid a disfiguring irregularity is a primary consideration in suturing a wound of the lip. Another consideration is the prevention of disfigurement by the almost inevitable contraction of the scar the linear contraction may result in a shortened lip with retraction of the mucocutaneous border and notching of the free lip margin. A depression along the line of the scar may also be due to contraction Linear contraction is eliminated by the halving and stepping techniques

Such characteristic anatomical features as the philtrum of the upper lip the white line and the orbicularis oris muscle should be respected to preserve normal contour when suturing the lip

The philtrum may be distorted by incisions placed diagonally across it the suture of the mid portion of the upper lip should therefore follow a vertical line unless the broken line method is indicated (Fig 66)

The intermediary white line between the mucosa and skin represents the culminating point of the prominence of the upper lip and should therefore be carefully adjusted.

When the continuity of the orbicularis oris muscle is interrupted the result is a deforming depressed area the muscle layer should thus be sutured before suturing the other layers of the lip

BREAKING THE SCAR LINE. Scars cutting across the folds of the face such as the nasolabial fold, may result in distortion and depression because of the linear pull of the scar Tension can be eliminated by excision of the scar and suturing after z plasty

The technique of simple excision of a scar and wound suture is shown in Figure 68

Prevention of Shock

Patients in shock exhibit symptoms and signs of extreme sympathetic stimulation regardless of etiology The physiological cause of shock is a discrepancy between capacity and content of the vascular tree. The usual surgical finding is loss of volume content in the form of whole blood plasma or electrolytes, individually or in combination (Cournand Riley Bradley Breed Noble Lawson Gregersen and Richards, 1943) Under circumstances of spinal anesthesia sepsis, or heart disease there is little or no loss of content but either the vascular capacity increases (Lynn Sancetta Simeone and Scott 1952 Ebert and Stead 1941) or the cardiac pump which normally maintains proper flow of the contents fails (Stead and Ebert, 1942 Freis, Schnaper Johnson and Schreiner 1952)

In elective surgery prevention of shock can be achieved by estimating the patient s state of health the amount of blood usually lost with the type of operation planned and the amount of ooze or drainage to be encountered during the postoperative period (Clark Nelson Lyons, Mayerson and De Camp 1947 Lyon Stanton, Freis and Smithwick 1949) Patients who have lost weight over several months and who are chronically depleted require several preoperative blood transfusions at divided intervals. They have been found to have normal red counts and hemoglobins but reduced blood volumes (Clark, Nelson Lyons Mayerson and DeCamp 1947) Paraplegic patients with large decubitus ulcers or burned patients with ungrafted raw areas are included in this category

The average blood loss of all operative procedures has not been measured a num

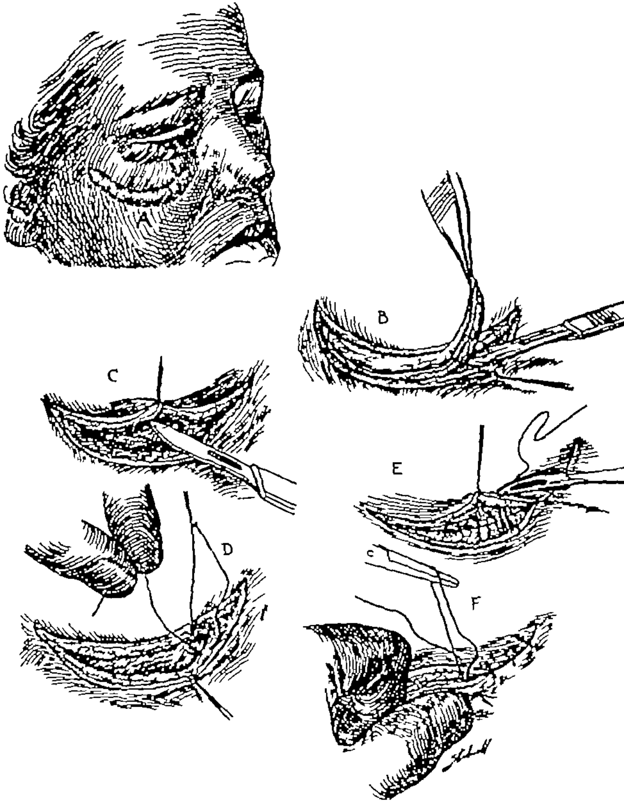


FIG 68. Technique of excision of a facial scar and suture of the wound

A. Outline of scar to be excised
B. Excision of the entire scar
C. Undermining the wound edges.
D Suturing the subcutaneous layer
E–F Suturing the skin

ber of values are available, however Dingman Ricker and Iob (1949) reported an average blood loss of 30 to 70 cc. in infants undergoing cleft lip and cleft palate surgery Coller Crook and Iob (1944) reported an average blood loss of 821 cc. for radical mastectomy Allbritten Lippschutz Miller and Gibbon (1949) found an average loss of 734 cc. of blood for a first stage thoracoplasty Royster Pendergrass Walker and Barnes (1951) reported a blood loss of approximately 2000 cc. for radical operations on patients with cancer of the head and neck. In five subjects the blood loss was found to vary between 130 and 409 cc. per hour during the first hour of surgery while skin flaps were being raised. During the third hour of surgery the blood loss rose to between 538 and 1037 cc. per hour during dissection of the tongue mandible and suprahyoid area Others have confirmed the magnitude of the operative blood loss (Bonica and Lyter 1951)

Although the blood loss measured when skin grafts are removed with the dermatome from the thigh back or abdomen averages only 46 cc. per drum of skin (Robinson 1949) considerable bleeding can occur after removing granulation tissue from the recipient bed (Moore Peacock, Blakely and Cope 1946) In patients with severe burns, the underlying nutritonal and metabolic disturbances can be only partially corrected before grafting rendering this group particularly vulnerable to loss from the circulating blood which under other circumstances would be well tolerated.

Following the completion of surgery there is considerable evidence of further loss of blood and serum which becomes important in the development of postoperative shock and anemia (Lyon Stanton Freis and Smithwick 1949) This continued loss is especially significant if the patient has not been adequately prepared previous to surgery or if operative losses have been only partially covered.

Therapy of Shock

Whenever shock occurs the patient should be placed in the Trendelenburg position immediately since this has been shown to improve the patient's condition for a brief period of time (Duncan Sarnoff and Rhode, 1944) A rapid infusion of isotonic saline is started in a femoral vein if easily entered or in the medial malleolar vein of the ankle, through a rapidly executed cut-down procedure (Cournand Noble Breed Lawson Baldwin Pinchot and Richards 1944) Blood samples for typing and cross-matching should be obtained by femoral vein or artery puncture before dextran is added to expand the plasma to avoid difficulties in cross matching of blood which occur after the administration of dextran

If the clinical appearance of the patient is that of severe shock, it may be estimated that a volume of about 2250 cc. of blood has been lost (Beecher 1949) Whole blood is preferable in the treatment of hemorrhage since adequate circulating hemoglobin is essential to assure both safe anesthesia and subsequent wound healing As much as 1500 cc. of dextran has successfully brought patients out of shock due to blood loss from lacerations not requiring further surgery and has also sustained them (Harrison Durden and Kellum 1955) this is not considered satisfactory treatment for an individual who may have to undergo anesthesia and extensive surgery (Beecher 1949) Under these latter circumstances equal parts of plasma expander and blood is recommended

Morphine should be given only for the relief of pain Most patients in severe shock do not complain of pain Morphine given subcutaneously or intramuscularly during shock is not absorbed, but is absorbed after the restoration of blood volume and blood pressure and may result in severe depression at an undesirable time (Beecher 1949)

The patient's body temperature is maintained by a cover of blankets to avoid

shivering Experimental evidence seems to indicate that under well controlled circumstances hypothermia combined with the administration of chlorpromazine or the barbiturates to prevent shivering extends the survival time of dogs in shock (Postel Reid and Hinton 1956) Application of this method of treatment in man has already begun to confirm these observations (Murray and Bruce, 1955) Heat applied to patients in shock, has been known to cause burns, since the circulation in the skin is inadequate to dissipate the heat.

Under circumstances of trauma or continuous blood loss from an operative wound surgery is thought to play an important role in shock therapy since certain types of hemorrhage can be controlled only by ligation or repair of blood vessels (Beecher 1949)

The use of l norepinephrine in the treatment of hemorrhagic shock seems to be indicated only when there has been poor response to what was estimated to be adequate volume replacement (Sokoloff King and Wechsler 1954).

Postoperative Measures

An important precaution after operations on the jaws under general anesthesia is to suction out the stomach contents before the patient leaves the operating room to diminish postoperative vomiting A nasal feeding *tube may be maintained for a few days* after operations involving the oral cavity to avoid contact of food with the operative site.

A Mayo cannula is retained to prevent laryngeal obstruction by the tongue until the patient begins to recover the laryngeal reflex If an intratracheal tube has been introduced, it is retained until the gag reflex reappears. Later the patient is placed in a mid Fowler position the movable frame at the head of the bed is elevated fifteen inches from the horizontal stationary frame The knees are flexed by raising the lower portion of the bed to prevent the patient from sliding downward

The mid Fowler position enables the patient to breathe freely as the abdominal contents gravitate away from the diaphragm In addition fluids are swallowed more easily Elevation of the head decreases the danger of postoperative bleeding which may occur following operations about the face particularly after nasal surgery *Changes to the horizontal position and frequent* flexion and extension of the knees are necessary to alleviate stasis in the pelvic veins. Early ambulation is particularly advisable following facial surgery

4

EARLY TREATMENT OF FACIAL INJURIES

Perhaps every practitioner of medicine is called upon at various times in his career to render service to a patient who has suffered facial injury Such emergencies may include common accidents such as knife wounds, cuts from flying glass, lacerations caused by a fall from a horse or a bicycle an automobile crash industrial mishaps resulting from carelessness or faulty mechanisms, injuries received during participation in sports such as skating baseball boxing fourth of July celebrations dog bites, burns of various kinds, and gunshot wounds resulting from hunting or other civilian pursuits.

The avoidance of permanent facial disfigurement and of serious functional disturbance is often dependent upon adequate primary treatment of such injuries. Because of these reasons, a resumé of emergency and early treatment is included in this chapter

ACCIDENT PREVENTION

Transportation Accidents

More than one million individuals suffered automobile crash injuries on the roads of the United States in the year 1956 Because such accidents are constantly increasing the causes and effects have been studied some of the facts learned in these investigations are of interest to those concerned with the early treatment of facial injuries.

Straith (1948) made a study of automobile crashes in the Detroit area. In order to reduce the forward displacement of the passenger as a result of a crash, the airlines early in their existence introduced safety seat belts (DeHaven 1953) Available information indicates that the bulk of injury producing automobile accidents occur with impact velocities of 40 miles per hour or less. Crash safety studies have indicated that the human body can be protected from death or serious injury for crash velocities of that magnitude.

At the Cornell Aeronautical Laboratories, using dummies in simulated automobile crashes time-motion characteristics of automobile occupants during crash decelerations were experimentally obtained by establishing the velocity of impact and the attitude and angle of the body at the instant of impact. The articulated dummies used for the study were dynamically similar to their human counterparts.

The findings in this experimental investigation indicated that the general motion characteristics of occupants of the vehicle under imposed crash conditions were of a predictable nature. The initial motion of the occupants was fairly consistent and repeatable the bodies were thrown forward and upward relative to the car at an angle of approximately 45 degrees. This complex accelerated motion ended abruptly when a major part of the body struck the interior of the automobile (Fig 69)

The driver of the vehicle sustained a chest blow against the steering wheel and a head blow against the upper windshield or adjacent molding this was a consistent

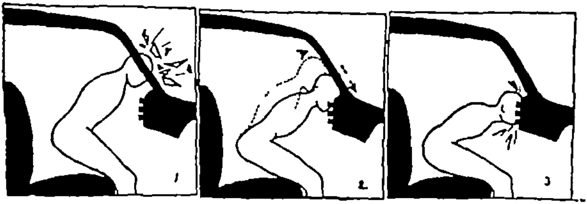


FIG. 69 Three typical types of guest passenger injuries Type 1—The head is thrown up forward, breaking the windshield head and neck cuts usually result. Type 2—Combination windshield cuts and crushing facial injuries result from these glancing blows. Type 3—Crushing and tearing injuries result from contact against the instrument board.

(C. L. Straith J A.M.A., 137:348, 1948)

finding The adult sized dummy in the right front seat struck the upper wind shield molding or headliner resulting in a blow of the head against the lower wind shield and a blow to the face against the top of the instrument panel The smaller dummy about the size of a six year-old child sustained an initial blow against the lower windshield or upper instrument panel and a secondary blow of the torso against the vertical face of the instrument panel

The specific motion of the occupant of the rear seat was found to be less predict able due to the greater distance traveled and the presence of intermediate objects which could be contacted thus deflecting the flight path The forward motion of the dummy initially located in the back seat usually terminated against the windshield or instrument panel area but the scatter prevented the determination of the specific spot which the body struck.

The use of high speed photographic tech niques proved valuable in determining the motion of the dummies. Aircraft type seat belts proved capable of either preventing a head blow or decreasing the impact energy of the blow The idea of "safe packaging the occupant of a vehicle entails padding the interior of the vehicle particularly areas such as the instrument panel or dash-board which the body of the occupant is apt to contact during a crash.

An analysis of 1000 automobile accidents (Table 1) and of 1678 injured persons (Braunstein 1957) revealed that one third of the injuries involved one body area only two-thirds of the injuries involved at least two body areas. 72.3 per cent of the cases suffered a head injury (Tables 2 and 3) of this number of head injuries 7.2 per cent also sustained fractures of one or more facial bones. The author of this analysis concluded that Casualty insurance companies settlements for personal injury more than double their settlements for property dam age Since this problem is of such major scope, certainly the training of the young surgeon should include instruction in the fundamental principles of plastic surgery "

TABLE 1
General Data

Data source	1000 automobiles in which crash injuries were sustained
Total occupants	2253
Total injured occupants	1678
Percentage of occupants injured	74 5%

Tables 1 2 and 3 are from Braunstein P W., J A M A. 163: 249 1957

TABLE 2

Head Injuries

Gross Type of Head Injury	Percentage of Injured Occupants	Percentage of Head Injuries
Skull fracture with facial fracture and soft tissue* injury	0 8	1 4
Skull fracture with soft tissue* injury	3 6	6 3
Skull fracture with or without other head injury	4 4	7 7
Facial fracture with soft tissue* injury	3 3	5 8
Facial fracture with or without other head injury	4 1	7 2
Soft tissue* injury only	49 2	86 6
Soft tissue* injury with or without other head injury		100 0
Total		100 1

* External.

TABLE 3

Frequency of Body Area Injury

Body Area Injured	Percentage of Injured Persons	Frequency Rank
Head	72 3	1
Neck and cervical spine	6 8	6
Thorax and dorsal spine	36 3	3
Abdomen-pelvis and lumbar spine	15 3	5
Upper extremities	29 4	4
Lower extremities	47 0	2

Face Injury in Sporting Activities

Facial injuries often result from participation in various sports. In a review of 150 face injuries by Gerrie (1954) 63 per cent involved the nose 25 per cent the mandible, 21 per cent the cheekbone 2 per cent the maxilla, 3 per cent the zygomatic arch and 5 per cent soft tissue.

EMERGENCY TREATMENT

Arrest of Hemorrhage

Hemorrhage is not too severe in most cases of facial injury and can be arrested by the application of pressure over the wound by placing the patient in a sitting position in bed to obtain elevation of the head and by sedation When nasal bleeding persists, additional procedures, such as packing the nasal fossae through the vestibules, or placing a postnasal pack in the nasopharynx are required (Fig 70) Clamping the bleeding vessel with a hemostat may be the only means of controlling pulsatile bleeding from an artery Ligation of the external carotid artery is indicated if other means of controlling bleeding are not successful

The sedation dosage for hemorrhaging patients should always be moderate in maxillofacial injuries with oropharyngeal bleeding Excessive sedation may eliminate the cough reflex permitting blood to trickle into the trachea while the patient is asleep, thus causing asphyxia.

Traumatic shock and shock due to hemorrhage is minimized by keeping the patient warm and quiet eliminating pain by sedation and by restoring blood volume with infusions of saline solution plasma or whole blood Transfusions of whole blood are necessary in case of severe hemorrhage

Prevention of Asphyxia

In severe injuries of the lower jaw the danger of asphyxia is immediately averted by protraction of the tongue (Fig 71) and by placing the patient in a prone position or in an upright position with the head flexed forward. The danger of laryngeal obstruction by backward displacement of the base of the tongue is increased in bilateral or comminuted fractures of the body of the mandible in the region of the symphysis. The geniohyoid and genioglossus muscles are attached to the genial tubercles on the inner aspect of the mandibular symphysis. Interruption of the continuity of this portion of the body of the bone by fracture results in a backward displacement of the mandibular symphysis which produces a relaxation of the musculature and allows the base of the tongue to fall backward, thus obstructing the epiglottic area and the laryngotracheal airway

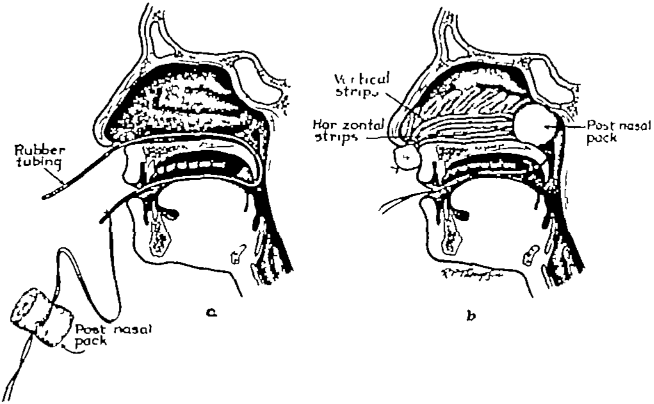


Fig 70 Technique of packing for the arrest of nasal hemorrhage

A. Technique of introducing a post-nasal pack.

B. Following the introduction of the post-nasal pack the anterior packing is accomplished by inserting horizontal strips in the lower part and vertical strips in the upper portion of the nasal cavity The horizontal strips are employed because they are easier to remove than vertical strips.

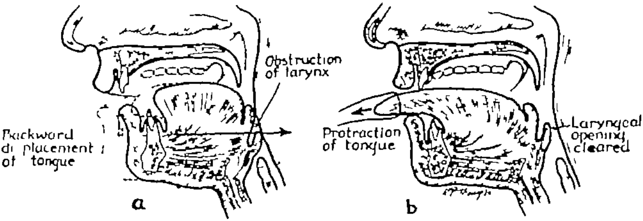


Fig 71 Relief of respiratory obstruction by protraction of the tongue

A. Backward displacement of the tongue obstructing the laryngeal opening following a bilateral fracture of the body of the mandible

B Relief of respiratory obstruction by protraction of the tongue

Forward traction on the tongue or immediate fixation of the mandibular fragments by interdental and intermaxillary wiring maintain the airway The Mosher lifesaver is a valuable instrument in an emergency when the preceding methods fail to relieve respiratory obstruction (Fig 72) it is a fenestrated cannula introduced into the laryngeal opening by way of the oral cavity In addition to maintaining the

airway the instrument serves as a guide to the trachea during tracheotomy for it can be palpated through the tissues

Tracheotomy

Tracheotomy the bypassing of the oropharyngeal airway and its replacement by an opening made directly into the trachea is required as an emergency lifesaving operation and is also employed as an elective procedure prior to surgery

Emergency Tracheotomy

Emergency tracheotomy is indicated if respiratory obstruction is not relieved by protraction of the tongue and mandible if edema around the base of the tongue and epiglottis or larynx is causing obstruction or if blood from oropharyngeal hemorrhage is flooding the airway Retraction at the suprasternal notch and supraclavicular fossa the intercostal spaces and epigastrium, restlessness, air hunger and cyanosis, rapid movements of the alae of the nose are all signs indicating that no time should be wasted in proceeding with an emergency tracheotomy

The patient is placed in a recumbent position with the neck extended the head is then immobilized The skin in an area extending from the mid line of the thyroid cartilage to the suprasternal notch is infiltrated rapidly with a local anesthetic solution A mid line skin incision is then made through the skin and subcutaneous tissue. Clamps are immediately placed over the cut sections of the isthmus of the thyroid in order to arrest bleeding The tracheal rings are then palpated immobilized between the thumb and forefinger the trachea is incised vertically in the mid line preferably at the third or fourth tracheal rings, and a canula is inserted.

In emergency procedures, it is useful to insert the Mosher lifesaver previous to performing the tracheotomy When the equipment is available and when time permits, a

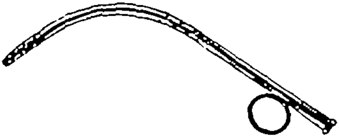


Fig 72. The Mosher Life-Saver

bronchoscope may be introduced through the laryngeal opening into the trachea thus simplifying the tracheotomy

Elective Tracheotomy

Simple measures such as protraction of the tongue maintain the airway in most cases of severe compound fractures which involve the mandible Such cases require constant surveillance this is impossible in unconscious patients or under conditions in which there may be a lack of trained personnel It may be necessary to perform a prophylactic tracheotomy before evacuating patients who must be transported to another hospital or evacuated under military conditions. In the Korean war for example, where helicopters were used for transportation of the wounded elective tracheotomies were frequently employed. Helicopters assured the rapid evacuation of the wounded only small sized helicopters were available and the patient was unattended during the flight a hazard in serious maxillofacial injuries. Prophylactic tracheotomy is a justifiable measure under such conditions. In a survey of a group of wounded men treated during the Korean war (Chipps, Canham and Makel 1953) 119 tracheotomies were performed for patients with maxillofacial injuries. No deaths could be attributed to tracheotomy no injured men died during air evacuation from Korea as a result of asphyxiation

Elective tracheotomy should also be employed in patients undergoing surgery for multiple fractures of both upper and lower jaws. Elective tracheotomy facilitates the

anesthesia the opening in the trachea being employed for the anesthesia

Many neurosurgeons feel that tracheotomy should be performed on any patient *suffering from a head injury who has been* in a state of coma for a period of over 24 hours. This measure is required in order to to maintain efficient aeration of the lungs because of the danger of partial respiratory obstruction from pharyngeal and tracheal secretions.

When performing an elective tracheotomy a horizontal incision is made in the lowest natural skin fold at the base of the neck. The skin incision should be adequate in length to compensate for the degree of exposure obtained by the vertical incision The advantage of the horizontally placed skin fold incision is the nearly invisible scar remaining after healing this is in marked contrast to the hypertrophic scar often observed after a vertical incision has been made at right angles to the natural skin folds of the neck particularly in young individuals.

CLINICAL EXAMINATION

Clinical examination of a facial injury to detect soft tissue and bone damage is essential for accurate early diagnosis, for it is thus possible to institute early methods of treatment to minimize deformity and functional disturbances. Examination may disclose only such minor injuries as superficial lacerations, abrasions or contusions of the soft tissues these however can result in conspicuous scars when improperly treated (Fig 73) More serious injuries, such as compound wounds and fractures involving not only the soft tissues but also the bones of the face may require more complicated and protracted treatment, success depend

Fig 73 Disfigurement resulting from inadequate primary treatment of wounds of the face incurred in an automobile accident. The scars are pigmented dust and dirt are imbedded in the wounds Note the large stitch marks over the right zygomatic area, caused by large size sutures.

ing on the use of proper methods in the early stages.

Facial injury may be associated with concomitant injuries such as head injury injury to the chest abdomen spine or extremities such conditions often require immediate lifesaving measures. If the patient's general condition permits facial wounds or fractures can be treated while an emergency operation is being performed in another area of the body Such procedures as reduction of a zygomatic fracture placing wire ligatures to immobilize fractured mandibular fragments or primary suture of soft tissue lacerations do not represent much added shock in the over all treatment of the patient they prevent facial deformity and functional disturbances and obviate the need for more complicated secondary procedures. When the general condition is serious, only the most essential measures can be undertaken other treatment must await improvement in the patient's condition.

Clinical Examination of the Injured Face

When first seen the appearance of a facially injured patient varies with the type of injury The patient may be holding a hastily prepared dressing over an open and bleeding wound or a handkerchief to a bleeding nose. He may be supporting an injured mandible, the mouth open saliva and blood drooling from the corner of the mouth. The patient may show marked swelling with closure of the eyelids and ecchymosis in the orbital area or be in an unconscious state due to a head injury Some patients, when first examined suffer severe pain others are numbed and shocked.

Soft tissue wounds vary considerably The wound may be abraded the surface of the skin having been scraped and the epidermis and outer layer of the dermis destroyed. In some abraded wounds there has been a penetration of grit or dirt which is tattooed into the soft tissue at the time of the accident (Fig 74) The wound may be

Fig 74 Abrased wound A patient whose face had been scraped causing loss of outer layer of skin Dirt particles are scattered under the skin surface.
(V H Kazanjian Tr Am. Acad. Ophth. & Otol 38 275 1933)

clean-cut such as the incised wound produced by a knife razor blade or glass. An area of skin and soft tissue may be ripped away from the adjacent tissue or the partially avulsed tissue may be hanging loosely in the form of a pedicled flap When the wound is produced by blunt force in contradistinction to the clean-cut lacerated wound produced by a sharp object, the wound edges are irregular markedly damaged and contused (Fig 75) Multiple punctate wounds, due to penetration into the skin of objects set in motion by an explosion form a cribriform skin wound designated as the sieve wound (Fig 76) Wounds may involve the soft tissues only or extend into the fractured underlying skeletal framework of the face producing a compound fracture. The gunshot wound is characterized by severe soft tissue and bone damage (Fig 77) Burns often cause a loss of skin of varying depths. If no soft tissue wound is present, contused or edematous areas may reveal the site of deep

Fig 75 (*Left*) Lacerated and contused wound resulting from aeroplane crash injury (*Right*) The same patient two weeks later following primary wound suture.
(J M Converse, Ann. Otol. Rhin. & Laryng 31:323 1944)

Fig 76. Sieve wound
(*Left*) Multiple facial wounds caused by secondary missiles projected by a bomb explosion
(*Right*) Same patient three months later following excision and suture of a large number of the scars

soft tissue injury or bone fracture A typical injury is seen following automobile crash accidents, in which multiple fractures of the facial skeletal framework may occur with little or no soft tissue injury (Fig 78)

X ray examination of the underlying skeletal framework determines whether the wound extends to the bone and is associated with a compound fracture Ecchymoses and swelling of the soft tissues may offer indi

FIG. 77 (*Left*) Gunshot wound of the jaw with little loss of soft tissue (*Right*) Closure by late primary suture.

(V H Kazanjian Am J Orthodontics, & Oral Surg 28:265 1942)

FIG 78 Crash injury Appearance of a patient with complex fractures of the face following an automobile crash. The wound over the nose shows the site of the impact. The maxilla is fractured and considerably displaced as evidenced by the open-bite and by the displacement of the floor of the right orbit. Evidence of the mandibular fracture is seen in loss of dental occlusion and loss of continuity of the dental arch.

cations of underlying bony damage. The presence of subconjunctival hemorrhage is an indication not only of possible damage to the eyeball but also of a fracture of one or more bones in the middle third of the face.

Fractures may be detected by the deformity resulting from displacement of bone particularly in the early stages after injury before swelling has appeared these include depression in the frontal area, distortion of the nasal framework depression in the region of the zygoma, nasomaxillary recession deviation of the mandible or disturbance of the dental occlusion. Difficulty in opening the mouth accompanied by pain is usually indicative of a jaw fracture Inability to open the mouth may

also be due to interference with the normal excursion of the mandible in the temporal fossa and impingement of a fractured zygomatic arch on the coronoid process of the mandible. Open bite suggests an impacted fracture of the maxilla a bilateral fracture of the body of the mandible or a bilateral fracture of the neck of the condyle.

When seen hours after the injury edema in addition to hemorrhage in the subcutanous tissues, tends to mask the deformity Hematoma of the face may be extensive for the loose facial tissues permit the collection of a mass of blood. Hematoma often masks changes in bony contour (Fig 79)

Palpation of the bony framework of the face is of assistance in diagnosis by revealing points of tenderness, areas of anesthesia due to nerve damge crepitus and undue mobility as well as loss of continuity with the adjacent bony framework Digital palpation of the skeletal framework includes palpation over the frontal bone the supraorbital ridges, the bones surrounding the orbit the zygoma and the maxilla Palpation of both infraorbital margins discloses

Fig 79 Hematoma of the face In severe trauma, subcutaneous bleeding of an artery may distend the tissues of the face thus making it difficult to determine the location of a fracture

Fig 80 Photograph demonstrating the disturbance of dental occlusion in patient with comminuted fracture of both maxilla and mandible Note that although there is contact between the teeth in the molar region, there is an open-bite between the anterior teeth.

notching at the junction of the zygoma and maxilla on one side if there is a fracture of the zygoma. Anesthesia in the area of distribution of the infraorbital nerve is an additional sign of zygomatic fracture. Palpation of the lateral wall of the orbit may assist in detecting loss of continuity between the zygoma and the frontal bone. Palpation over the zygoma may reveal an abnormal depression in the area due to fracture Abnormal mobility and crepitation may be noted over the nasal framework when palpating the nose.

Intraoral examination may show a disturbance in the normal occlusal relationships of the teeth indicating a fracture with displacement of a portion of the jaw (Fig 80) The upper teeth may occlude posteriorly to the lower teeth there may be an open bite or a space between the anterior teeth a deviation of the jaw to one side may be detected by comparing the median line between the central incisors of maxilla and mandible Intraoral palpation may reveal filling of the posterior portion of the upper buccal sulcus in the

case of a depressed fracture of the zygoma as well as tenderness in this area. Points of tenderness situated along a fracture line in the maxilla may also be revealed By grasping the teeth of the upper jaw between the thumb and index finger undue mobility of the upper jaw indicates a fracture of the bone Similar palpation of the lower jaw may detect points of tenderness or abnormal mobility and crepitation significant indications of fracture

Examination of the eyes, nasal fossae and ears are necessary in all facial injuries. Intranasal examination permits the detection of septal hematoma septal fracture and dislocation. Inspection of the external auditory canal may show obliteration of the canal from a subperiosteal hematoma of the anterior wall a sign of fracture of the tympanic plate occasionally accompanying a fractured posterior wall of the glenoid cavity the tympanum may be ruptured or bulging due to hematoma of the middle-ear cavity Examination of the eyes in a facially injured patient is discussed in detail in the following portion of the text because of its importance in permitting early diagnosis of ocular disturbances and impaired vision

Examination of the Eyes

Examination of the eyes after a facial injury should always include a thorough examination of both eyes. Trauma from flying particles concussions and explosions frequently cause intraocular injury without external manifestations. Early diagnostic clues are obtained from observation of the degree of exophthalmos and clinical observations of the media and fundi The biomicroscopic and transilluminator should be employed. Observation of ocular motility the action of the levator palpebrae superioris, frontalis and other facial muscles may also reveal dysfunction

The full extent of a laceration of an eyelid is sometimes concealed by edema and ecchymosis and by the presence of coagulated blood exudate and fibrin which must be removed from the wound surface before the laceration can be completely seen. Ocular tension may be ascertained by palpation of the globe through the upper lid Corneal sensation is tested before tonometry is done under topical anesthesia Comparable palpation of the orbital rims and zygomatic prominences may reveal bony suture separation displacement of fragments crepitation and emphysema. Visual acuity accomodation tests, and visual field studies are done as soon as conditions permit. Injury to the optic nerve may result from direct or indirect traction on the nerve between its attachment to the globe and the optic formen early diagnosis of this type of injury may be obscured by vitreous hemorrhage Hematoma within the sheath of the optic nerve is accompanied by decreased visual function spreading from the macula toward the periphery within a few hours. Examination reveals narrowing of the retinal arterioles venous congestion and peripapillary flame-shaped hemorrhages and small hemorrhages surrounding the macula Hemorrhage in the vaginal spaces of the optic nerve may cause secondary hemorrhages within the globe

Extensive hemorrhage within the orbit may occur as the result of direct or indirect injury to the vessels of the orbit and surrounding parts, or from intracranial vessels. Accumulation of blood behind the eye which results in "compression herniation of the globe (Fig 81) usually extravasates from the trunk of the ophthalmic veins, ophthalmic artery or other vessels within the orbital apex. Intraorbital hematoma can also originate from bleeding in the eyelids, which if not restrained by the septum orbitale progresses to the deep portion of the orbit.

Fractures of the bones forming the orbital walls may result in rupture of the vessels in the diploë of the bone causing direct bleeding into the orbit. One of the problems that may arise with voluminous

FIG 81 Extensive hemorrhage in the orbit within ten hours of its onset. This late hemorrhage occurred about sixty-five hours after a wound by numerous small bodies from an antipersonnel mine.
(B. Smith Tr Am. Ophth. Soc., 49:673 1952)

intraorbital hemorrhage is the inability to occlude the lids over the cornea In such cases an emergency procedure can be done to decompress the orbit by incising through the septum orbitale to evacuate the hematoma. The incision should avoid injury to the levator palpebrae superioris, the extraocular muscles and the lacrimal gland De-compression of the orbit by removal of the lateral wall of the orbit is an alternate procedure in severe cases.

Careful examination of the orbital structures should include the possibility of muscle and nerve injury Direct trauma should not be overlooked in considering the etiology of extrinsic muscle paralysis. Penetrating sharp small caliber objects frequently cause more damage to deep orbital structures than the surface wound indicates. Rupture contusion laceration and intramuscular hemorrhage are usually caused by foreign bodies in the orbit Displaced fragments of the fractured roof of the orbit occasionally impinge directly upon the levator palpebrae superioris or adjacent extraocular muscles. Injury to the oblique muscles occurs as a result of direct trauma or indirectly as a result of disturbance of the superior oblique pulley Depressed fractures of the frontal sinus frequently displace the pulley

Rupture of the iris sphincter from contusion of the eyeball often results in mydriasis. Transillumination of the globe aids the visualization of sphincter separation unless the pupil is obscured A curved deformity of the pupil may be present at the point of separation of the sphincter

Temporary blindness from injuries in the orbital region is most commonly due to blepharospasm resulting from corneal irritation or fright. Delayed swelling of the eyelids may progress to a stage in which active lid opening becomes impossible and passive opening of the lids is difficult. Direct injuries to the anterior segment of the eye or hemorrhage in the anterior chamber may reduce vision to light perception More extensive blunt injury to the globe may cause rupture of the fibrous tunic of the globe. Any perforation or rupture of the globe is accompanied by decreased intraocular pressure and may be detected by a pulp-like feeling when palpating the globe through closed eyelids.

Hemorrhage into the vitreous cavity may be attended by separation of the retina Opacity in the vitreous sometimes nullifies light perception and obscures fundus details. Posterior rupture of the globe or evulsion of the optic nerve are also characterized by a soft and flabby eyeball

Hemorrhage into the sheath of the optic nerve may create sufficient intrathecal pressure to interfere with the transmission of impulses through the optic nerve resulting in blindness. Fractures of the orbit extending through the optic canal cause enough reaction to obliterate light perception and create a predisposition to cystic atrophy

Specific localization of magnetic foreign bodies in the orbit is facilitated by roentgenography and local application of the Berman locator Radiotransparent foreign bodies are usually non magnetic and are

often difficult to localize. Large intraorbital foreign bodies may displace the orbital contents causing a non pulsating exophthalmos (Smith 1952)

Facial Injury Associated with Head Injury

In fractures of the frontal bone or the nasal bones and the maxilla with comminution and displacement into the ethmoidal labyrinth, brain injury and a tear of the dura with cerebrospinal rhinorrhea are possible complications (Chapter 10) One should suspect cerebrospinal rhinorrhea when a hemorrhagic fluid clearer than blood is exuding from the nose. The possibility of a head injury should not be eliminated even in the absence of suspicious signs. Brain injury or fracture of the skull may occur by contre coup for example a blow on the chin often producing a fracture of the mandibular condyle may also result in fracture of the body of the mandible and the base of the skull by transmitting the force by way of the mandibular condyles to the floor of the middle cranial fossa

Craniocerebral injury should be suspected in a patient with a facial injury who is or has been inconscious who has paralysis of one or more of the cranial nerves or who demonstrates monoplegia hemiplegia or paraplegia abnormal reflexes, convulsions or delirium such injury may be considered probable in the presence of bleeding from one or both ears or when lumbar puncture reveals blood in the cerebrospinal fluid Positive signs are direct visualization of a fracture of the frontal bone through the wound escape of pulsating clear fluid from the nose or ear and positive roentgenographic findings such as a fracture line displaced fragments, or an aerocele.

Roentgenographic Examination

Radiological examination of the facial skeleton is required to detect fractures in facial injuries The technique is discussed in Chapter 18

Prophylaxis against Tetanus

Active immunization with toxoid reduced the incidence of tetanus to a low figure among wounded United States Army personnel only one case was reported in the European theater of operations by February 1 1945 (Graham and Scott, 1946) It is useless to administer toxoid to an injured person who has not been actively immunized since the development of antibodies is too small and too late to prevent tetanus 1500 American Units of antitoxin should be given however and repeated at weekly intervals until three doses have been administered. A patient who has already been actively immunized by toxoid should be given a booster dose of 1 cc. at the time of injury Tetanus may occur late after the excision of a healed facial scar or even one year after a bombing injury as observed in a patient treated by one of us in Great Britain during World War II The patient had not been previously immunized and the *Clostridium tetani* was liberated from the scarred tissues, resulting in a fatal case of tetanus.

TREATMENT

Treatment should be initiated only after the anatomical damage has been evaluated and diagnosis is made The soft tissue wound may be closed by primary suture a procedure which is described in the following pages. In compound fractures treatment should be undertaken from the bottom up reduction and fixation of the fractured bones are performed previous to surgery of the soft tissues. The intraoral manipulations required for the treatment of jaw fractures can disrupt carefully sutured soft tissue wounds of the lips and cheeks if this sequence is not followed

Minor Procedures

A number of simple measures performed at the bedside provide the patient with

a degree of comfort even in serious cases, and are also helpful in subsequent treatment If the patient is being subjected to an operation for a major injury such as fracture of the skull concomitant minor operative procedures such as reduction of a nasal or zygomatic fracture or primary suture of a lacerated eyelid can be accomplished without undue risk while the patient is under anesthesia Additional procedures are completed when the general condition has improved.

Primary Suture of Facial Wounds

Soft tissue wounds should be sutured as soon as possible after the accident for primary healing is the goal in the treatment of facial wounds. Bacterial contamination is not followed by clinical signs of infection during the first hours after injury The period during which primary suture of facial wounds is permissible following injury depends on the type of wound and the judgment of the surgeon While primary suture of facial wounds is best performed during the first few hours after injury the rich vascularization of the facial tissues permits successful primary suture of clean-cut lacerations as late as twenty hours after injury Clinically evident infection and rapidly increasing swelling of the soft tissues occur early in contused crushed and mangled wounds Primary suture of such wounds should be performed during the first few hours after the excision of ragged wound edges and devitalized tissue

The lids should be sutured as soon as possible to protect the eye even though a later secondary procedure may be necessary to correct distortion due to loss of tissue because laceration of the eyelid may result in exposure of the eyeball

It is good procedure to cleanse the wound and skin around the wound in the operating room The meticulous removal of dried caked and adherent dressings, and saline irrigation to cleanse the wound of small foreign bodies is best done by the surgeon. A mild detergent syringed into the wound may assist in the removal of foreign bodies and damaged tissues. Washing the area with soap and water or with a detergent is better than applying strong and often painful antiseptics. Aqueous Zephiran 1 1000 is not painful to the open wound or to the eyes.

Local anesthesia is most satisfactory in uncomplicated facial injuries. Bleeding vessels should be clamped vessels that persist in bleeding are tied with fine ligatures. Blood clots are removed and devitalized tissue excised Irregular ragged skin edges are resected. Because of the rich blood supply of the facial tissues a more sparing excision of the wound edges may be effected than in other parts of the body

Fine subcutaneous and subcuticular sutures are used to eliminate dead space and to approximate the base of the dermis (Fig 57 Chapter 3) The skin should be undermined when the wound edges cannot be approximated without tension because of tissue loss produced by the excision of the skin edges. Buried sutures are inverted and the knots are tied in the depths of the wound The purpose of buried and subdermal sutures is to relieve all tension on the wound edges and the externally placed skin sutures. Approximation of the skin edges of the wound can be obtained with fine, interrupted skin sutures placed to avoid inversion these should be sufficiently numerous to insure apposition. Such prepared sutures of fine silk or nylon with atraumatic needles attached are available in sterile glass tubes, and can be kept in readiness for emergency suture of a facial wound. Fine skin sutures sizes 5 0 6 0 may be retained in the tissues for periods varying from four to seven days and do not leave suture marks unless tied with undue tension When careful primary suture is performed later secondary repair is often unnecessary (Fig 82)


FIG 82. (*Left*) Appearance of patient three weeks after primary suture of a wound of the face sustained when the patient was thrown from a horse. The nose, upper lip and maxilla were split. The tissues were readjusted by suture and the maxillary fragments brought together by wiring

(*Right*) Appearance of patient six years after injury The scars have become effaced. The initial operation had restored the facial contour

(Figs. 82 to 84 from V H Kazanjian Surg Gynec. & Obst. 72:431 1941)

Partly Avulsed Flaps of Facial Tissue

The rich vascularization of the face permits survival of flaps of partly detached tissue which remain attached to the facial tissue even by narrow pedicle.

The decision to preserve flaps of skin attached to the surrounding tissues only by a tenous pedicle depends upon surgical judgment. The following case history illustrates a typical problem of this sort. A patient riding in the right front seat of an automobile was thrown head first through the windshield which was shattered, the edge of the broken windshield causing a gouging and the avulsion of a flap of skin and subcutaneous tissue of the left cheek extending over an area of 10 by 6 cm The flap remained attached by a small pedicle and was maintained by an emergency dressing When examined in the hospital the flap appeared blanched, resembling the color of a full thickness graft after its removal from the host bed The pedicle of the flap was only about 7 mm. wide, obviously inadequate to maintain the blood supply The flap was transformed into a full thickness graft by excision of the subcutaneous fat. It was then sutured and maintained with a pressure dressing until revascularized In some instances the decision to maintain the attachment of partly detached tissue as a pedicled flap or to sever its connection and transform it into a graft, is a more difficult one to make. The flap assumes a deep cyanotic color because the pedicle, although sufficiently wide to allow the passage of arterial blood is too narrow to permit adequate venous return Because the arterial blood pressure is greater venous congestion occurs in the flap Preservation of such a flap is hazardous. When the cyanotic tinge is less accentuated, however or when digital pressure on the flap causes blanching and is followed by a rapid return to color thus demonstrating the efficiency of the dermal vessels of the flap the chances of survival are good

The rich vascularization of facial tissues and the possibility of survival of a flap of partly avulsed facial tissue are well illustrated by the following case history of Larrey (1817) in relating his experiences during the Russian campaign. A Russian colonel one of the first patients brought to the hospital had received from one of our cavalry men a sabre cut that had cut his nose at its base along its whole length The sabre had struck obliquely and had extended the division of the tissues down to the two canine teeth and into the thickness of the maxillary bone at the level of the nasal fossae The palatine vault was part of the turned-down flap hanging on the chin The flap remained attached to the remaining living portions of the face by two small flaps of the upper lip at the angle of the mouth on each side. One could see the entire extent of the nasal fossae and of the oral cavity The flap comprised the entire nose the upper lip and the palatine vault and was turned down over the chin One of my assistants, having found this flap cold and held only by the two small pedicled flaps previously mentioned was prepared to sever the flap and dress the wound. When I arrived by the side of the wounded man I pushed away the scissors of the surgeon and after examining the wound made arrangements to suture it. It was difficult to remove the clots of blood filling the nasal fossae as dust had made them hard and firm. I detached from the flap the portion of the palatine vault consisting of the anterior half of the superior alveolar arch which was separated from the rest of the jaw I also detached a number of loose fragments of the nasal bones and the frontal processes of the maxilla. I then brought together the lip and the nose and proceeded to their union by interrupted sutures beginning at the root of the nose and descending on each side The wound edges were approximated by ten sutures A piece of soft cloth fenestrated and soaked in salt water was applied on the entire surface of the triangle comprising the wound I introduced into the nostrils two large pieces of rubber tubing to keep the form and the diameter of the nostrils. They were fixed to the skin of the face by means of threads passed through their anterior extremity Compresses were placed on each side of the nose and a supportive bandage completed the dressing I had the great satisfaction of learning on my return to Moscow that this field officer was completely cured and showed no deformity This cure is remarkable because of the gravity of the wound and also because of the small number of vessels which maintained a communication between the flap and the integuments of the face. Life had returned to the nose and its reunion with the edges of the wound was exact and perfect."

Primary Suture of Full Thickness Wounds of the Eyelid Which Involve the Eyeball

Lacerations of the eyelid should be sutured as soon as possible in order to protect the globe and prevent distortion of the eyelid Horizontal lacerations are sutured by direct approximation after trimming irregular or ragged wound edges. Vertical full thickness lacerations of the lid are sutured by the stepping and z plasty methods in order to break the straight line which would result in contracture of the eyelid (Fig 67 Chapter 3)

The edges of the wound are spread in order to thoroughly examine the cut sections of the eyelids. This permits inspection of the conjunctival fornices and eyeball The presence of a disrupted fragmented globe may be indicative of sympathetic ophthalmia arising from retained unidentified remnants of the uveal tract. All the fragments should be raised on a continuous suture before being excised because additional hemorrhage is caused when each remnant is excised separately When enucleation is indicated an implant

should be buried immediately if sufficient Tenon's capsule and muscle cone are present in order to counteract possible contraction. Lacerations of the conjunctiva are closed later to reform the conjunctival fornices. Smooth, perforated acrylic, glass or plastic of suitable size and conformation is placed within the repaired socket to prevent adhesions, excessive subconjunctival edema and conjunctival herniation; the lid margins are then approximated by sutures.

Late Primary Suture of Facial Wounds

Open wounds become edematous and infected if they have not been closed by primary suture. Suturing an inflamed and edematous facial wound rarely produces a satisfactory result.

Late primary suturing is successful only after preliminary preparations which include cleansing the wound, moist dressings, maintaining free drainage, immobilization with pressure dressing and antibiotic therapy. Even badly infected and contused facial wounds can be prepared for suturing in from two to ten days. The wound becomes filled with pink, healthy appearing granulations and the surrounding redness and edema subside. Devitalized tissue is then excised and the wound is sutured (Figs. 83, 84).

When healing is fairly well advanced it may be preferable to permit spontaneous

FIG. 83. Late primary suture. Photographs of a child showing a facial wound treated by late primary suture. The wound had been sustained when the child ran against a wire fence. Suture was performed three days after injury.

(*Left*) Initial wound.

(*Right*) Photograph taken two weeks later.

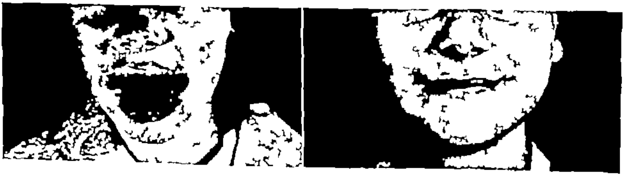


FIG. 84. Late primary suture.

(*Left*) Contused wound seen 48 hours after a gunshot accident. This wound is unsuitable for immediate suture.

(*Right*) Result obtained by late primary suture performed three days later.

FIG 85. (*Left*) Photograph of the face after a firecracker explosion. Minute particles of powder are embedded in the skin.

(*Right*) Appearance of the patient after thorough cleansing under general anesthesia. The remaining particles were removed with the aid of a small corneal trephine. Many of these particles eventually work their way to the surface.

healing of the wound and to plan a secondary repair of the scar

Powder Marks and Foreign Bodies

Small particles of dirt and powder scattered superficially under the skin result in disfigurement In some accidents for example when the patient has been dragged along a road minute foregin bodies imbedded in the abrased area produce a tattooing effect In other cases, as observed in emergency wards following the accidental explosion of fireworks, particles of powder are peppered into the face leaving innumerable scattered bluish dots in the skin (Fig 85) These foreign bodies become encapsulated if not removed immediately and permanent marks remain The points of entry are still open during the first twenty four hours it is therefore imperative that vigorous treatment be instituted early The affected area should be cleansed with soap and water and scrubbed deeply imbedded particles can be scooped out with a fine dental excavator or with the tip of a sharp-pointed knife The patient should be anesthetized during the procedure which may be time-consuming binocular magnifying loupes aid in the detection of particles.

In the treatment of superficial tattoo marks of long standing dermabrasion (Chapter 16) should be attempted but when the foreign bodies extend deeply into the deep layers of the dermis and the subcutaneous tissue the most satisfactory technique is the excision of the area followed by closure of the defect.

Loss of Soft Tissue

When only a small or moderate amount of tissue has been lost the skin edges should be undermined to relieve tension before suturing A small rotation or transposition flap is occasionally used to fill the defect A free split thickness skin graft dressing should be applied to the raw area whenever the defect is too large to be closed by direct approximation or by a local flap this primary skin graft is particularly indicated in avulsions of the frontal and scalp regions.

When direct approximation of a flap from the adjacent area is a doubtful pro

cedure a skin graft will provide a temporary covered healed wound Later reconstructive procedures may require excision of the temporary skin graft and the repair of the defect by local or distant flaps, depending on the extent of the defect.

The following case is an example of adequate early treatment The patient div ing into a swimming pool struck his face against the bottom and suffered an avulsion of an area of skin from the bridge of the nose The area was too large to approxi mate by primary suturing A free full thick ness retroauricular graft placed over the defect resulted in a satisfactory permanent repair Had the graft not proved satisfac tory it could have been excised in a sec ondary stage and the resultant defect closed by local flaps

Closure without distortion is not possible in extensive full thickness loss of cheek tis sue. A satisfactory method is to suture the edge of the mucosa to the skin edge to mini mize contraction When an acrylic mold can be tolerated, it is placed in the area thus preventing contraction of the tissues and distortion of the surrounding region until reconstructive measures are undertaken

Traumatic Amputation of Eyelid, Nose or Ear

The tip of the nose or a portion of the ear or cheek are sometimes accidentally severed. Tagliacozzi (1597) and Ambroise Paré (1575) reported successful replacement of severed portions of the nose or ear Carpue one of the surgeons responsible for the revival of Indian rhinoplastic methods in Europe at the beginning of the nineteenth century translated the following case history told by Garengeot (1731)

On the 26th of September 1724 a soldier of the regiment of Conti coming out of an inn was attacked by one of his comrades and in the struggle had his nose bitten off so as to remove almost all of the cartilaginous portion His adversary perceiving that he had a bit of flesh in his mouth spat it out into the gutter and endeavored to crush it by stamping upon it. The soldier who on his part was not less eager took up the end of his nose and threw it into the shop of Monsieur Galin a brother practitioner of mine while he ran after his adversary During this time M Galin, examined the nose which had been thrown into his shop and, as it was covered with dirt, he washed it at the well The soldier returning to be dressed M Galin washed his wound and face which were covered with blood with a little warm water and then put the extremity of the nose into this liquor to heat it a little Having in this manner cleansed the wound, M Galin now put the nose into its natural situation and retained it there by means of an agglutinating plaster and bandage. Next day the union appeared to have taken place and on the 4th day I myself dressed him with M Galin and saw the extremity of the nose was perfectly united and cicatrized

Keegan (1900) states that Hoffacker was officially appointed to attend the duels which took place among the students at Heidelberg Broad-swords were the weapons used in these encounters and Hoffacker writing in 1828 described 16 cases in which portions of the nose lips and chin, after having been sliced off were replaced and became reunited.

Accidental amputation of portions of the face occur in automobile accidents as a result of razor or knife slashes or bites by dogs or humans The amputated part, wrapped in a handkerchief, is often brought by the patient. The structures most frequently amputated either partially or completely are eyelids and portions of the nose or ear Survival is possible if the part remains attached, even by only a narrow pedicle because of the ample blood supply of the facial tissues Replacement and suture of the partially detached portion of the nose or ear into its original position often results satisfactorily Complete amputation

however presents a far more difficult problem

The successful replacement of completely severed portions of the facial tissues is largely dependent on the type as well as the size of the detached portion When a flap of skin and subcutaneous tissue is completely avulsed from the cheek if the detached portion of tissue is available it may be successfully replaced after it is transformed into a full thickness graft by removing the subcutaneous fat from the undersurface of the dermis, as described earlier in the text Successful reattachment of completely severed composite structures such as the nose ear and eyelid is dependent not alone upon the size of the detached portion but also on the amount of raw surface contact between the amputated structure and the site of reimplantation The wider the surface of contact the greater the possibility for successful revascularization of the transplant. The chances of success are better in young individuals than in the older patients.

Full thickness loss of eyelid tissue rarely occurs independently from serious damage to the eyeball Callahan (1956) reported successful retransplantation of eyelid tissue avulsed by a human bite during a bout of sexual enthusiasm (Fig 86A)

A woman aged 22 experienced a bite of her right upper lid When she was brought into the hospital shortly after injury at 3 A.M on Sunday morning she did not bring the detached portion of the lid with her Her friends were dispatched to the scene of the injury for it

Examination showed a large central coloboma of the right upper lid The defect in the tarsus measured 5 mm vertically by 15 mm horizontally the defect in the skin and orbicularis was about 10 mm vertically by 15 mm horizontally The rigidity of the tarsus and the angle of bite caused less tarsus to be lost than skin Tooth marks were evidenced by the V-shaped notch torn in the tarsus at each end of the colobom right eye was uninjured.

The detached portion of the li found on the floor with some tras brought back to the hospital A nig tendant placed it in an envelope c patient s chart. At 8 A.M it was rec by a resident who placed it in a me glass filled with penicillin solution (units per cc.) This detached portion single piece the size of the defect, and been bitten off squarely

The plan for repair was to use the and lid margin of the detached lid p to discard the skin and obicularis, sliding flaps of muscle and skin to fo anterior lamina and to prevent d from postoperative contracture (v tension) by uniting the upper lid wi lower along a wide intermarginal ad (Fig 86B C and D)

The patient s inebriation had su sufficiently by 9 a.m for repair to be

When transplantation of the eyelid is not possible because of destruction c the eyeball remains exposed partic when the upper eyelid is lost Dessic of the cornea from lack of corneal p tion initiates a keratolytic process terminates in destruction of the eye.

Protection of the eye is imperative avulsed eyelid tissues cannot be rep When the lower eyelid is destroyed c of the upper lid protects the cornea tection of the cornea cannot be a when the upper eyelid is destroyed lower lid is separated into muscular c ous and tarsoconjunctival layers (Ch 21) The inner tarsoconjunctival layer vanced to cover the globe the musc taneous layer is advanced as far as po and the remaining raw area over the conjunctival layer is covered with a graft

The eye is in serious danger when upper and lower eyelids are avulsed tioning the inferior rectus muscle p

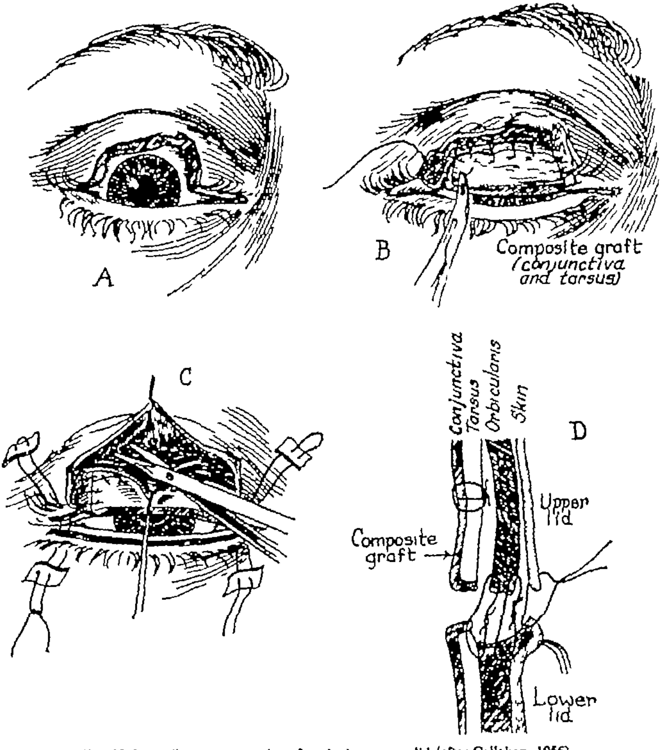


FIG 86 Immediate reconstruction of avulsed upper eyelid (after Callahan, 1956)
A. Illustrates the defect resulting from human bite (see text)
B. The detached avulsed portion of the lid denuded of skin is sutured to the edges of the defect.
C. Mobilization of the orbicularis oculi muscle fibers and of the skin
D. Diagram showing method of placing sutures.

upper rotation of the eyeball and protection of the cornea until later reconstructive procedures can be considered.

Amputated portions of the nose vary from a small segment involving the tip of the nose to a major portion of the nasal pyramid. In the replacement of the detached portion the recipient bed should be prepared by excision of the torn crushed or devitalized tissues and by careful hemostasis. Survival of a large amputated segment of the nose is doubtful because the

surface of contact between the transplant and the bed is small

Small segments of composite auricular tissues may be replaced with a probability of success, but the replacement of a major portion of the auricle is problematic because of the small surface of contact between the edge of the detached ear and the stump The auricular cartilage should be preserved because it is valuable for future reconstruction A relatively simple technique consists of removing the skin from the auricular transplant and imbedding the cartilage beneath the skin in the auricular area if the skin is in good condition an alternative is to place the auricular cartilage in a subcutaneous pocket beneath the skin of the abdomen for future reconstructive procedures.

A detached portion of the ear may be preserved by placing the tissue in a sterile container and in an ordinary refrigerator for skin may be preserved for a period up to 3 weeks in temperatures ranging from 1 to 5 degrees above zero Centigrade (Chapter 15)

Trap-door Flaps

Trap-door flaps (Fig 87) often constitute a difficult problem. They are usually due

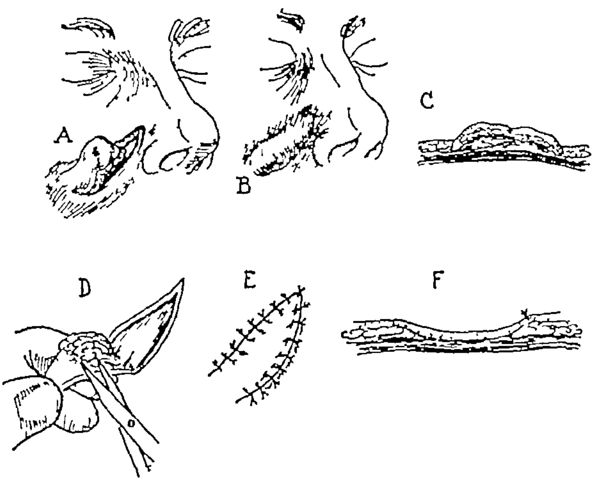


Fig 87 Technique of repair of trap-door flap

A. Illustrates the tendency for the trap-door flap to contract upon itself

B. A typical appearance of trap-door flap after healing in contracted position.

C. Cross-section showing contracted trap-door flap

D The trap-door flap is transformed into a full thickness graft by excision of the subcutaneous adipose tissue from the dermis.

E. Flap-graft sutured into its bed.

F Cross-section illustrating the flap replaced as a free full thickness graft The tendency for contraction of the graft is less than that of the flap

to the gouging out of skin and subcutaneous tissue by a protruding object as on the dashboard of an automobile or by a broken bottle. The survival of the detached flap offers no particular dilemma when the trap-door has a wide base. The survival of the tissue however becomes problematic if the trap door is long with a very narrow base. If there is any doubt about the survival of the tissue the subcutaneous fat is excised from the base of the dermis and the replaced tissue is maintained by a pressure dressing (Fig 87*E*, *F*)

Another problem associated with the trap-door flap is the manner in which such a flap heals the scar tissue forming on the undersurface of the flap tends to contract the flap upon itself resulting in an ugly convex, puckered appearance of the flap (Fig 87*A* *B* *C*) Because the flap is surrounded by a scar on three sides, the lymphatic and venous drainage from the flap tends to be sluggish such flaps may therefore remain edematous for a long period of time, until venous and lymphatic drainage is re-established. It is best to completely excise the trap-door flap and to approximate the edges of the resultant wound by direct suture when the flap is small enough to permit this procedure, and when the area is one in which the postoperative scar will not be too noticeable (Fig 87*D*)

Injury to the Parotid Gland and Duct

Penetrating wounds of the parotid gland (Fig 88) may involve the facial nerve causing facial paralysis (Chapter 27) When leakage of clear fluid is noted in a deep wound of the posterior cheek region the parotid gland or Stensen's duct has probably been injured The skin may be sutured over the fistula if the parotid gland alone is sectioned. Parotid fluid leakage through an open wound ceases spontaneously after scar tissue forms in the wound We have never observed a parotid gland fistula which did not close spontaneously usually within a

Fig 88. Deep destructive wound in the parotid region with facial paralysis.

few days or at the latest within three or four weeks.

Facial lacerations which involve the parotid duct are not common as Stensen's duct is a relatively short structure situated over the anterior surface of the gland and in front of the masseter muscle Wounds in the region of Stensen's duct however should be carefully examined because of the possibility of injury to the duct which should be suspected whenever deep lacerations of the cheek cross a line extending from the inferior border of the external acoustic meatus to a point mid way between the ala of the nose and the upper border of the lip (Fig 89) This line approximates the level of the duct.

The cut ends of the duct may sometimes be seen when inspecting a fresh wound Salivary flow often apparent from the proximal cut end, may appear spontaneously or may be elicited by pressure over the gland In cases of injury to the duct, when diagnosis is uncertain it is possible to thread a polyethelyene catheter through the ostium and the duct until the tip appears in the wound If the ostium is not easily located in the mucosa of the buccal wall the area is dried and painted with a dye such as methylene blue or mercurochrome the ostium stains darker than the surrounding tissue In order that access to

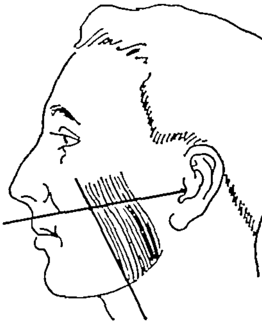


FIG. 89 Method for locating Stensen's duct at the intersection of a horizontal line extending from tragus to the mid portion of the upper lip and an oblique line parallel to the anterior border of the masseter muscle.

FIG. 90 The severed parotid duct syndrome consisting in paralysis of the upper lip due to section of the buccal branch of the facial nerve and swelling of the face from collection of saliva escaping from the severed parotid duct. Note laceration by razor slash on left cheek.

the duct be facilitated the cheek should be retracted outward, thus straightening the distal portion of the duct and making it more accessible.

A typical clinical picture of severance of Stensen's duct is exemplified in a patient who had primary closure of a laceration of the cheek over the anterior portion of the masseter muscle and who experienced a soft tissue swelling of the cheek and a drooping of the upper lip on the side of the injury (Fig 90) The swelling appeared after a meal and gradually increased in size. The clinical examination revealed fluctuant liquid collection in the cheek aspiration with a needle and syringe showed a clear fluid. This fluid was salivary secretion from the parotid gland which accumulated in the loose tissues of the face after the sectioning of the duct. *Drooping of the upper lip* resulted from severance of the buccal branch of the facial nerve, a branch of the nerve in close proximity to the duct.

Injuries in the masseteric portion of the duct are most favorable for repair for in this part of its course the duct is straight relatively immobile and its walls are thick and tough The wall of the duct becomes much thinner and branches appear in the region of the parotid gland this portion of the duct may be hidden by the overhanging margin of the gland

Injuries to the duct are frequently complicated by associated injuries to the gland substance and by damage to the facial nerve The buccal branch of the facial nerve parallel to the duct may be just superior to it or may cross it (Fig 91)

The treatment of a sectioned parotid duct varies. Among the methods advocated are the creation of an internal fistula communication from the proximal end of the duct permitting salivary flow into the mouth ligation of the proximal end of the duct resulting in atrophy of the gland and direct anastomosis of the severed duct

Malgaigne (1874) advised making a new fistula into the mouth from the proximal

portion of Stensen's duct. He used silk sutures these were brought out through the oral mucosa and the ends of the sutures were then tied into a knot This method has been successful in our hands Malgaigne stated that Claude Bernard, experimenting with horses, noted that obliteration of Stensen's duct caused rapid atrophy of the parotid gland. Malgaigne suggested ligation of Stensen's duct as the procedure of choice in the treatment of parotid duct fistula

Morestin (1917) described his experiences with sixty two cases of salivary fistula secondary to war wounds thirty of these involved the gland only thirty-two arose from the duct. He described numerous instances in which fistulas of either the gland or the duct underwent spontaneous repair as the result of cicatricial obstruction. Morestin eventually adopted surgical ligation of the duct and suture without drainage of the soft tissues in persistent fistulas of the duct following extensive experience in the creation of internal fistulas Of thirteen cases of ligation of the duct, eleven healed promptly A transient collection of saliva which disappeared after aspiration or drainage occurred in two cases.

Repair of the severed duct by suture (Fig 92*A*) is done after passing polyethylene ureteral catheters, sizes varying from No 2 to No 4 into the ostium toward the cut end of the duct (Fig 92*B*) or in a retrograde direction from the cut end of the duct into the oral cavity In order to facilitate the passage of the catheter through the duct, the cheek wall should be retracted outward. This maneuver straightens the angulated course of the duct (Fig 92*C*) and permits easy passage of the catheter (Fig 92*D*) which after being brought out through the cut section of the distal segment, is threaded into the cut section of the medial segment the two sections of the duct are then approximated over the catheter (Fig 92*E*, *F*) Sutures of 6-0 silk on atraumatic cutting needles are used for anastomosis the sutures are passed through

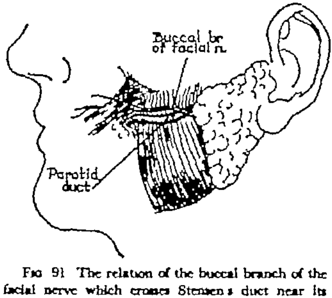


Fig 91 The relation of the buccal branch of the facial nerve which crosses Stensen's duct near its origin

the full thickness of the duct wall. The end of the catheter is brought out around the angle of the mouth and fixed to the cheek by means of adhesive tape The catheter should be retained for a period of a week to ten days.

When the severed ends of the parotid duct cannot be repaired by direct suture, Malgaigne's method of creating an internal oral fistula can be employed. An incision is made through the oral mucosa and extended through the soft tissues until the area of the fistula is reached A number of nylon sutures are placed through the soft tissues of the cheek and the ends of the sutures are left to protrude through the incision in the oral mucosa The skin wound is closed and a pressure dressing applied The nylon sutures are not tied they are pulled out after the internal oral salivary fistula is established

Should these procedures fail due consideration should be given to ligation of the proximal end of the duct, usually located by observing the salivary flow when pressure is exerted over the parotid gland

Soft Tissue Wounds Associated with Fractures

Facial wounds frequently occur in association with fractures in the more severe types of injuries A laceration of the cheek

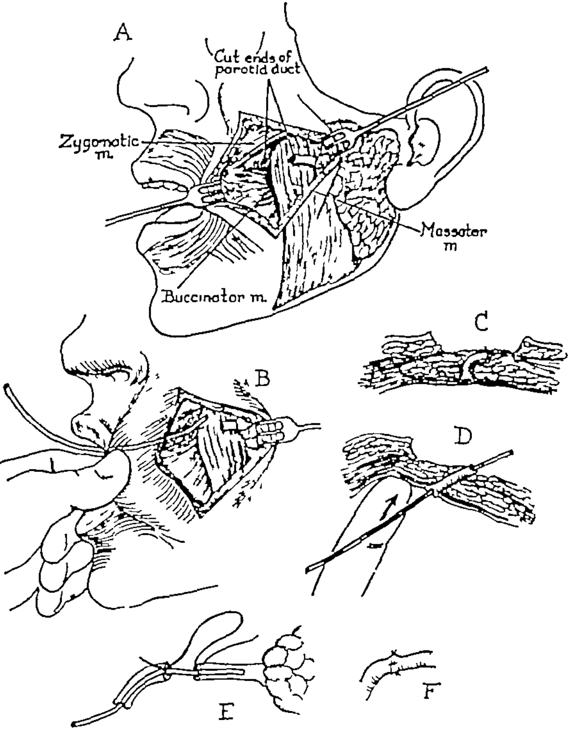


Fig 92. Repair of the severed parotid duct

A. Illustrating the severed duct at the anterior border of the masseter muscle

B A fine-calibered polyethylene catheter is threaded through the buccal opening of Stensen's duct.

C. Illustrates the angulation of Stensen's duct as it penetrates through the cheek wall. This angulation renders difficult the penetration of the catheter into the duct

D Outward stretching of the cheek wall tends to straighten the duct and facilitate the threading of the catheter through it.

E. Direct anastomosis of the cut ends of the duct using the catheter as a splint

F Appearance after suture of the cut ends of the duct.

for example, may occur coincidentally with a mandibular fracture. Compound fractures are characterized by an external wound which leads to the fracture site. The treatment of soft tissue wounds associated with fractures does not differ from that of other facial wounds the sequence in which the two types of injury are treated however is an important consideration As a rule, reduction and fixation of fractured bone fragments should precede wound suture. Fracture reduction restores the anatomic position of the soft tissues disruption of the soft tissue wound by the necessary intraoral manipulation in the treatment of fracture is thus avoided A few hours delay in which to provide the required fixation of the bone fragments does not jeopardize the successful closure of the soft tissue wounds.

GUNSHOT WOUNDS

Gunshot wounds result in a disorganization of the tissues and a great amount of tissue damage Such wounds are almost invariably associated with fractures and comminution of the bones of the face. Tissue injury varies according to the speed, size shape and striking angle of the projectile and to the dispersion of bone or tooth fragments which act as secondary missiles churning through the tissues and leaving a path of devitalized tissue and an extensive wound of exit (Fig 93)

Fig 93 Destructive gunshot wound of the middle portion of the face. Structures in the nasal cavity lower and left side of the nose, anterior portion of the maxilla and hard palate are destroyed. There is severe contusion of soft tissues.

The true loss of tissue is usually not extensive. The exaggerated size of the wound is due to factors which include retraction of the borders of the wound caused by contraction of severed muscles, elasticity of the surrounding skin local inflammatory reaction and edema, the weight of detached flaps of tissue, and displacement of the fragments (Fig 94) Facial wounds with or without initial loss of soft tissue or bone may eventually result in considerable loss of tissue through infection or osteitis.

Clinical Examination

Examination should disclose the nature of the wound and the physical condition of the patient

The extent of damage is estimated more easily in large gaping wounds an evaluation of the damage is more difficult in lacerations the roentgenogram is indispensable The extent of bone and tooth destruction laceration of the buccal mucosa and damage to the floor of the mouth tongue and pharyngeal tissues should be assessed.

Wounds of the Upper Portion of the Face

Comminution of the frontal bone usually involves the frontal sinuses and the frontal lobe, requiring neurosurgical care (Chapter 10) Fractures of the cribriform plate of the ethmoid or of the orbit may also involve the frontal lobe of the brain.

Wounds of the Middle Portion of the Face

Injury to the upper lip may vary from laceration and slight loss of tissue to com

FIG 94 (*Left*) Photograph showing a detached flap of tissue consisting of the lower lip the anterior part of the mandible and a portion of the floor of the mouth, hanging loosely the patient was wounded by a shell fragment

(*Right*) The composite flap has been replaced the mandibular fragment has been immobilized by a splint and the soft tissues sutured Anatomic continuity is restored

plete destruction associated with loss of the lower part of the nose A great deal of bone may be destroyed when the maxilla is comminuted The loss of the upper lip is almost invariably associated with mutilation of the anterior part of the maxilla (Fig 95) The entire maxilla and the septum of the nose are destroyed in some injuries.

Wounds of the Lower Portion of the Face

Gunshot wounds of the lower lip chin and symphysis cheek and body of the mandible vary in severity Extensive comminution may result in loss of bone without loss of soft tissue Gaping wounds of the lower lip chin and the floor of the mouth may be accompanied by a considerable loss of bone (Fig 96) Extensive destruction of the lower portion of the face occurs occasionally the patient survives because vital structures are rarely damaged in this area in contrast to wounds of the upper and middle portions of the face Early repair of the soft tissues can often be achieved by employing adjacent tissues. The soft tissue flaps retract when not sutured early owing to infection and fibrosis, and the apparent loss of tissue appears greater than it really is.

Wounds of the anterior part of the maxilla and mandible characterized by extensive destruction of the teeth and comminution of the bone do not usually lead to alarming complications if adequate treatment is effected at an early period Wounds involving the posterior part of the face however and especially those of the pharyngeal and cervical regions, are particularly hazardous. Such injuries may involve the larger blood vessels causing severe primary or secondary hemorrhage. Laryngeal obstruction occurs more frequently in gunshot wounds of the jaw because bilateral fracture of the mandible or comminution of the anterior portion of the mandible may result in a backward pull by the genioglossus, geniohyoid and mylohyoid muscles the tongue falling backward toward the pharynx and obstructing the

Fig 95 Gunshot wound of the middle portion of the face

(*Left*) Extensive wound with destruction of the anterior portion of the maxilla and of the nose caused by shell fragment.

(*Right*) Reconstruction obtained by late primary suture eight days after injury The tissues of the upper lip are supported by a prosthetic appliance constructed previous to operation. Nasal reconstruction was achieved in a later stage.

Fig. 96 (*Left* and *Center*) Gaping gunshot wound of the lower portion of the face with loss of soft tissue and extensive loss of bone.

(*Right*) Prosthesis in place, to maintain the anatomic position of the two lateral fragments of the mandible and to serve as a framework for later reconstruction of the soft tissues.

(V H Kazanjian, J Oral Surg 1 30 1943)

laryngeal opening Edema due to tissue injury and infection may spread from the floor of the mouth into the neck causing respiratory obstruction and requiring emergency tracheotomy

Injuries to the Tongue

The tongue which almost fills the entire oral cavity when the mouth is closed is subject to serious injury If the wound is limited to the apex or dorsum, the profuse blood supply promotes rapid healing even in cases of severe injury If the base of the tongue is penetrated serious hemorrhage may ensue through involvement of the lingual arteries. Fragments of bone and teeth driven into the tongue convey infection and may elude detection or localization even by roentgenography

Destruction of the anterior part of the tongue does not usually eliminate function hemi-atrophy may result from hypoglossal nerve injury Tongue function becomes limited when adhesions form between it and the floor of the mouth such adhesions necessitate secondary correction

Treatment Phases of Gunshot Wounds

The treatment of gunshot wounds of the face under military conditions can be divided into three phases. The immediate phase which extends from the time of injury and shock to one or two days following is a critical period. Primary suture of facial wounds may be performed at this time under favorable conditions. The surgical treatment may be complicated by the need for evacuating the patient to a specialized unit In most cases treatment consists of providing the patient with the type of treatment that will prevent further damage to the injured tissues during evacuation immobilizing displaced fragments of the jaws insuring patency of the airway administering antibiotics and giving adequate sedation to relieve pain.

Healing of the wound occurs in the second phase which extends over the following two or three weeks complications such as infection and secondary hemorrhage may occur The treatment consists of further immobilization of bone fragments by means of ligatures or fixation appliances, and supporting the soft tissues by prosthetic appliances and dressings. Late primary suture may be performed in this pre-reconstructive phase Much can be done during this period to reduce deformity and facilitate later reconstruction.

The third phase is the period of reconstruction performed after the tissues have healed Problems related to late reconstructive surgery of deformities resulting from gunshot wounds are considered in other sections of this book This section is devoted to the treatment of gunshot injuries during the first two phases after emergency measures have been taken to assure the survival of the patient.

Immobilization of Fractures

The fractured bones should be immobilized by intra-oral appliances consisting of wires, bands, dental arch bars and the use of wire or elastic traction These early therapeutic measures can usually be performed under local anesthesia Early immobilization is a comfort to the patient and hastens the healing of the wounds. The soft tissue wound is reduced to its true dimensions by restoring the anatomical relationships of the tissues after the bones have been replaced (Fig 97). It is essential that intra oral treatment and the insertion of fixation appliances are completed before the soft tissues are sutured (Fig 98) intra-oral manipulation may retard healing of soft tissue wounds.

Primary and Late Primary Suture of Gunshot Wounds in War and Peace

In casualties occurring in warfare much depends upon whether the patient can be given a definitive type of treatment early or whether he must be evacuated to another installation for this purpose Such

FIG. 97 (*Left*) Comminuted compound fracture of the mandible in the region of the symphysis forty-eight hours after injury resulting from gunshot wound.
(*Right*) Restoration of the normal contour after immobilization of the jaw fragments by removal of loose detached pieces of bone, and late primary suture of soft tissue performed ten days later

conditions vary whether warfare is stationary or mobile. In World War I for example a stationary type of trench warfare existed for long periods. Under such conditions installations were placed in strategic positions to treat the wounded In World War II however such relatively fixed conditions were not usual for a mobile type of warfare prevailed.

Primary closure is possible only in wounds with little loss of tissue but is not feasible in wounds with appreciable loss of soft tissue without either risking tension of suture lines and distortion of the tissues or undertaking a more complicated type of repair such as the transfer of a flap failure complicates definitive reconstructive surgery One must also consider the extent of damage to the bones. Fixation appliances may be required in severe comminution to maintain the remaining fragments. Treatment of the soft tissues must be delayed under such conditions.

The treatment of gunshot wounds by primary suture during World War I resulted in many failures. For this reason primary suture of gunshot wounds was not advised during World War II. Some successful primary closures of facial wounds were reported probably due to a better understanding of the treatment of wounds and the prompt services of well-equipped maxillofacial teams. Similar successful closures of facial wounds were reported during the Korean War When properly repaired in the first 24 hours, closure is accomplished before edema occurs and with adequate antibiotic therapy the maxillofacial wound heals with a minimum amount of scarring Closure of an extensive facial wound improves the morale of the patient and offers every advantage to the surgeon. Primary healing after primary closure eliminates an open wound painful dressings, loss of saliva difficulty in feeding and infection and suppuration.

In a recent series of cases of primary closure during the Korean War (Chipps, Canham and Makel 1953) failure occurred in approximately one-third of the cases these were attributed to the following causes (1) Tight closure of the wounds

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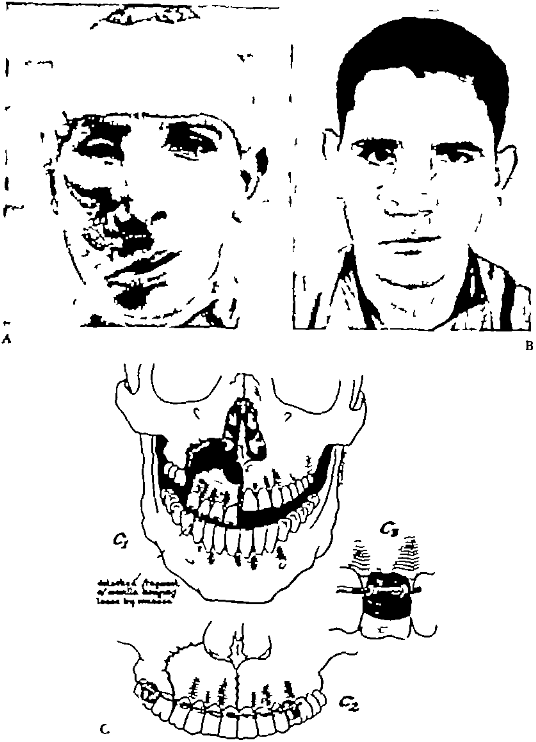

Fig. 98. Photographs showing gunshot wound of the middle portion of the face involving the soft tissues and including a compound fracture of the maxilla.

A. Appearance of the patient four days after injury previous to treatment.

B. Appearance of face after late primary suture of the wound.

C. The first step in treatment. Immobilization of the fragment.

C-1 Diagram of the displaced fragment.

C-2 Immobilization of the fragment.

C-3 Enlarged view of anchorage.

(J. M. Converse, J. Oral Surg. 3:112, 1945.)

without provision for deep tissue drainage. Accumulating fluid such as saliva and serum from a wound adds to the tension on the wound edges and constitutes a medium for the multiplication of infective organisms. (2) Inadequate immobilization of the wound by an improperly applied pressure dressing which permits the wound to fill with blood or exudate and failure to immobilize the jaws. (3) Failure to adequately close the oral mucosa exposes the facial wound to contamination by oral fluids and decaying food debris, to movements of the tongue and to mechanical irritation by food (4) Secondary hemorrhage resulting from the breakdown of a ligated major blood vessel or more frequently as a result of infection (5) Secondary manipulation required when a fracture has been inadequately reduced and an intra-oral fixation appliance must be adjusted.

For these reasons adequate immobilization of the fractured mandible is essential before primary wound repair If the fractured bones are correctly aligned and immobilized, the construction of a more complicated and more definitive type of fixation appliance should await the complete healing of the soft tissue wounds.

It may be noted that the early closure of the maxillofacial gunshot wound is not contraindicated but that the success of such a closure is directly proportional to the attention given to standard surgical principles of debridement, hemorrhage control proper suturing adequate immobilization of tissues and drainage as well as adequate antibiotic treatment. All of these details in the treatment are conditioned by the circumstances under which the patient is being treated and are extremely variable in warfare.

Late Primary Suture of Gunshot Wounds

While recent experiences have demonstrated the possibility of achieving success by primary suture a large proportion of gunshot wounds are treated by late primary suture because of a number of reasons The surgeon's services may not be available until after edema has developed deeply situated devitalized tissue or foreign bodies may be difficult to remove, or loss of tissue may be too extensive to permit suture of the wound edges by direct approximation or by local flap transfers.

All maxillofacial wounds are contaminated Cleansing can be achieved by local warm irrigations, employing an irrigator can with a glass tip and pressure hose and nozzle with sufficient pressure to wash away food debris necrotic tissue, and dirt or foreign bodies. It is necessary to establish dependent drainage in order to avoid puddling secretions or exudate in a cul-de-sac.

Gunshot wounds may often be prepared for suturing within the first two weeks. The operation is performed when the wound is filled with healthy pink or bright red granulations when suppuration has ceased when the wound edges are not edematous and when inflammation has subsided Infection is controlled by the administration of antibiotics.

Excision of the wound edges is necessary because it rids the wound of infected tissue pus-producing granulations and scar tissue

Wounds with extensive loss of tissue cannot be repaired adequately at an early period Much can be accomplished, however by suturing radiating wounds, lacerations of lip borders and the nose or eyelids By such treatment the various parts are assembled the picture of the wound is simplified and unnatural and distorted healing is prevented (Figs. 97 98)

Secondary Hemorrhage

Secondary hemorrhage occurs most frequently between the fourth and twelfth days. It is therefore important when major blood vessels are in the proximity of infected wounds to watch for signs of hemorrhage and to maintain equipment for the control of hemorrhage at the bedside, to

retain the tracheotomy tube if present, and to postpone evacuation of the patient during this critical period (Chapter 6)

Nutrition of the Maxillofacial Patient

The patient undergoing prolonged maxillofacial treatment requires a special diet. Such diets are usually available for patients who are unable to masticate. Severely wounded patients or those undergoing definitive surgery cannot assimilate these diets when taken orally It has been found, however that when nasal feeding tubes are inserted before or soon after the admission of the patient and retained during the definitive treatment stage satisfactory nutrition of the patient is achieved

The use of the nasal feeding tube offers the great advantage of eliminating possible contamination of the wound by food The mouth may be cleansed after oral feeding by means of a spray or by mouth washes these procedures, however cause a certain amount of mechanical irritation which may interfere with normal wound healing In all cases undergoing surgery involving the oral cavity and in patients whose jaws are occluded by intermaxillary fixation we prefer to utilize a nasal feeding tube for a few days until the patient is able to take oral feedings. In Korea a marked clinical difference was observed in patients who were fed by nasal tubing and those who were permitted oral feedings the tube-fed patients appeared stronger and showed less weight loss oral wounds were made ready for closure earlier and the postoperative healing period was shorter An additional advantage of the nasal feeding tube is the ease of administering drugs ordinarily given by capsule a difficult procedure in the oral fed patient undergoing treatment for a fractured jaw

There are a number of disadvantages, however to the use of nasal tubes. Some patients complain of pharyngeal pain this is frequently observed in patients who have received endotracheal anesthesia An ulceration of the posterior pharyngeal wall may develop occasionally if a nasal feeding tube is retained for more than two weeks. In some cases the tube is not tolerated by the patient for psychological reasons.

In maxillofacial wounds with considerable tissue loss which require complicated early methods of treatment and prolonged restorative procedures, the nasal feeding tube must be retained for a prolonged period in such cases, gastrostomy is indicated before nutritional imbalance occurs.

CARDINAL PRINCIPLES IN THE TREATMENT OF MAXILLOFACIAL WOUNDS WITH LOSS OF TISSUE

The rules to be observed in the treatment of wounds in which substance has been lost may be summarized as follows

1 *The anatomical relationships of the remaining bony tissues should be preserved* The necessity for immobilizing the remaining fragments of the mandible and maxilla in correct occlusal relationship has been emphasized the soft tissues are more adequately repaired after the bone fragments are immobilized

2. *When suturing soft tissues over a bone defect the anatomical contour should be supported by an intra-oral appliance* Soft tissue sutured over an area of the mandible from which bone is missing will collapse inward in the course of the healing process, thus resulting in a distortion of the soft tissue contour which remains difficult to correct A prosthetic mold should be provided early it may be constructed to fit over the intra-oral appliance which is employed to immobilize the bone fragments (Figs. 136, 137 Chapter 6)

3 *An inner lining should be provided as well as an outer covering in suturing soft tissue wounds of the cheeks and lips* Deficiency in the lining results in intraoral contraction during healing An adequate lining can be provided from the adjacent mucosa or by the use of a skin graft Mucosa

because of its quality of elasticity may be utilized in the oral cavity to cover even large defects

4 *Wounds should not be sutured under tension* The blood supply is diminished when tissues are stretched and approximated by tight sutures, thus interfering with healing Tension results in distortion. Skin grafting or a local flap may be necessary to cover the defect in order to prevent tension

5

INTRODUCTION TO FRACTURES OF THE FACIAL BONES

Fractures of the facial bones are the result of either direct or indirect injury A fist blow to the face is an example of direct injury the forward projection of the face upon the dashboard in an automobile crash is an example of indirect injury The type of fracture *depends upon the severity and* direction of the impact The striking force may result in fracture of a single bone without displacement fracture with displacement comminution of bone or fractures involving a number of bones. Comminuted fractures have increased in number due to the severity and frequency of crash injuries which have paralleled the increase in the speed of motor vehicles. In automobile crash injuries, the direction of the blow is determined in part by the position of the victim at the time of impact In dashboard or windshield accidents the head is tilted *forward backward or to one side* therefore the site of the impact on the face varies.

An associated soft tissue wound in a compound fracture depends not only upon the violence of the force but also upon the nature of the object striking the soft tissues the occurrence of a soft tissue wound is thus greater when the face is thrown against a sharp or protruding object

A blow striking the frontal region of the head may produce a fracture of the frontal bone or a depression of the supraorbital arches into the frontal sinus. In the central portion of the middle third of the face fractures may result in a backward displacement of the nose fracture of the nose with deviation of the nasal pyramid occurs if the blow strikes the nose laterally A direct head-on injury over the middle third of the face may result in fracture of the maxilla *depending upon whether the head is tilted* backward or forward the displacement of the fractured maxilla being upward and impacted or downward and loose Severe crash injuries cause multiple fractures involving the bones of the middle third of the face with gross backward displacement. Injury to the lateral portion of the middle third of the face may cause a fracture of the zygoma which involves the orbit

Blows on the mandible at the symphysis may produce fracture of the condyles of the ramus, or bilateral fractures of the body of the mandible A blow striking the side of the jaw usually results in a *fracture lateral* to the symphysis on one side and of the condyle or of the ramus of the mandible on the other side

Types of Fractures

The break through the bone may be linear in type or multiple lines of fracture may be present constituting a comminuted fracture

The presence or the absence of displacement of fractured bone fragments depends upon the location of the fracture line its direction and also upon the direction of

muscle pull upon the fragments The fracture is termed closed or open depending upon whether the overlying soft tissues are intact or exposed by a soft tissue wound the open type is generally referred to as a compound fracture Fractures involving the jaw are frequently accompanied by a tearing of the oral mucosa thus transforming a closed fracture into an open or compound fracture. Fractures may also be complicated by infection which causes sequestration and loss of bone and arrests the healing process of the bone.

Reduction and Fixation

When the fragments are displaced the first procedure in treatment is to re-establish the normal position of the fragments. After these have been placed in their proper relationships, the immobilization or fixation of the fragments must be assured.

Reduction

Reduction of the fracture or realignment of the fragments can often be achieved manually and immediately by manipulating the fragments. Reduction may also be accomplished progressively by means of continuous applied traction Open reduction involves the exposure of the ends of the fragments and their alignment under direct vision

Fixation

After reduction fixation of the fragments is unnecessary if there is no tendency for displacement. As a rule however fixation is required for the muscular action upon the fragments tends to cause displacement. Employing the method first advocated by Gilmer (1887) in fractures of the mandible, wires may be placed around the teeth thus maintaining alignment of the fragments.

Dental arch bars and bands prepared for intermaxillary fixation and specially constructed for each case are often essential to achieve properly controlled fixation of the separated fragments. The design and construction of these appliances require judgment and skill When such fixation appliances are not available prefabricated metal arches can be fixed to the teeth by fastening them with stainless steel wires or various types of wiring made of alloyed metals.

New anesthesia techniques and the use of the antibiotics have simplified direct surgical procedures in the fixation of fractured facial bones. In oblique fractures of the mandible circumferential wiring may be employed Fixation may also be obtained by means of pins placed through the skin into the fragments thus retaining the fragments in the corrected position Various types of external fixation have been employed using twin converging pins or screws A bone graft wired to each fragment can serve as a means of immobilizing the fractured mandible when loss of bone has occurred.

In some fractures of the facial bones, especially of the maxilla fixation of the fragments often requires skull anchorage, a method described also as cranial fixation.

There is thus a choice both in methods of reduction and fixation of fractures Each case must be considered individually the treatment selected should be the one which will achieve results in the simplest and most rapid manner

The Time Factor

Treatment may be early delayed or late depending upon the rapidity with which the patient reaches the surgeon and upon the condition of the patient and the availability of the means for treatment. Early treatment is initiated either immediately after the accident or within forty-eight hours after injury Delayed treatment usually extends over the first few weeks after the injury before consolidation of bone occurs. Purposeful delay in the reduction of a fracture is decided upon when the condition of the patient does not permit immediate interference Late treatment is required

if the fractured fragments have consolidated in faulty relationships and resulted in a malunited fracture

Healing of Fractures

Healing of the fracture is governed by biological factors with which the mechanical measures must be co-ordinated to obtain bony union and restoration of form and function When the continuity of a bone is interrupted loss of function is due in part to skeletal instability Tissue reaction to bone injury and loss of function consists of trauma and inflammation with subsequent formation of callus and new bone. The fragments which aid in the regeneration of a new bony arch should be preserved in comminuted fractures.

Fracture causes hemorrhage from soft tissues and bone. An inflammatory reaction of the tissues occurs around the site of the fracture following hemorrhage. The process of bone repair is not initiated until the inflammation subsides. Granulation tissue then invades the fibrin network of the hematoma the hematoma is resorbed by phagocytosis. Instability of the ends of the fractured bone may interfere with the formation of granulation tissue at this stage

Osteoblasts are found in the area following resorption of the hematoma it is not certain whether osteoblasts are formed by metaplasia of fibroblasts or whether they originate entirely from osteoblasts of the fragments which form the callus and are located principally along the external and internal surfaces of the cortex in the vascular canals and in the cancellous spaces and bone marrow The osteoblasts deposit their long collagen fibers and a cement substance is laid down between them thus forming osteoid tissue Calcium is then deposited The callus does not show the regular pattern of normal bone cells in its early stage and is not revealed distinctly on the roentgenogram at the consolidating fracture because most of the calcium is deposited in the cortical layer not as yet formed in the newly formed callus. Complete repair of the fractured bone may not be apparent in the roentgenogram until calcification is completely achieved

Fibroblasts are replaced by osteoblasts during the healing process of a fractured bone. Adult fibrous tissue is formed when conditions favor the multiplication of fibroblasts over that of osteoblasts. Adult fibrous tissue or scar tissue between the ends of the fragments prevents infiltration of osteoblasts and deposition of calcium. Mechanical movement and infection at the fracture site favor the predominance of fibroblasts over osteoblasts resulting in non-union of the fracture

Early reduction and maintenance of fragments in alignment and contact by techniques which permit the impaction of the fragment ends are important factors in the healing of fractures. Such favorable conditions stimulate the formation of callus and protect it from injury thus permitting orderly ossification

Factors which result in non union of *mandibular fractures are predominantly* local The most important of these is the lack of bony contact of the fragments. This may be due to a number of causes which include insufficient immobilization displacement of fragments, faulty fixation by splints with the fragments too widely separated or inadequately impacted aseptic necrosis of fragment ends, interposition of soft parts, and infection these interfere with the healing process in both the open and closed fracture

If the fracture remains non-consolidated for a sufficient length of time the damaged intermediary callus becomes fibrous and a false joint space is established. If non union is of long standing the fragment ends become eburnated When this stage has been reached non-operative measures are of no

avail in such cases it is necessary to restore the continuity of bone by bone grafting

Most fractures of the facial bones, other than fractures of the mandible heal rapidly because the fragments are not subjected to strong muscular activity Adequately immobilized mandibular fractures consolidate in four to six weeks

6

FRACTURES OF THE MANDIBLE

THE MANDIBLE: ANATOMICAL CONSIDERATIONS

The mandible, consisting of a body and two rami, is a moveable bone articulated with the cranium by means of the temporomandibular joints and connected with other bones of the face and cranium by ligaments and muscles. Although the mandible is a strong bone with a thick cortex and contains but little spongiosa, it is exposed to trauma and because it is a relatively flat bone it may be fractured by a lateral blow. The movements of the jaw are governed by the action of various muscles attached to the mandible. When a break in the continuity of the mandibular arch occurs, the muscles aid in the displacement of the fragments.

The Teeth

The surgeon should be aware of the correct occlusal relationship of the dentition (Fig. 99) because the normal dental occlusion, serving as a guide in the re-establishment of separated fragments, provides a positive index for restoring the masticatory efficiency of the teeth. When dental occlusion has been re-established, the bone fragments have usually been placed in good functional alignment.

Immobilization of the fragments is facilitated when sound teeth are present on one *or both sides of a fractured jaw*, for the teeth provide an ideal means of anchorage.

When teeth are injured or deprived of their blood supply, which is often the case in fractures, the pulp becomes infected and the infection may spread along the traumatized area. Vital teeth are of advantage for purposes of immobilization; devitalized and infected teeth in the line of fracture may be a source of additional difficulties.

The anterior teeth of the maxilla normally overbite corresponding teeth of the lower jaw; the lingual cups of the bicuspids and molars articulate with the occlusal surface of the corresponding lower teeth. With the exception of the lower central incisors and the upper third molars, each tooth is usually opposed by two other teeth.

Casts of the maxillary and mandibular dentition are made to verify occlusal relationships. Examination of the worn surfaces of the cusps of the teeth are often an aid in re-establishing the occlusion when fracture results in displacement.

Muscles of Mastication

The muscles attached to the mandible play an important role in the displacement of fragments. These muscles may be divided into a posterior group which includes the elevator muscles of mastication and an anterior or accessory group of masticatory muscles.

Posterior Group

The muscles attached to the ramus of the mandible are the masseter (Fig. 100*A*), temporalis (Fig. 100*C*) and internal and external pterygoid muscles (Fig. 100*D*); the general direction of the pull of these mus

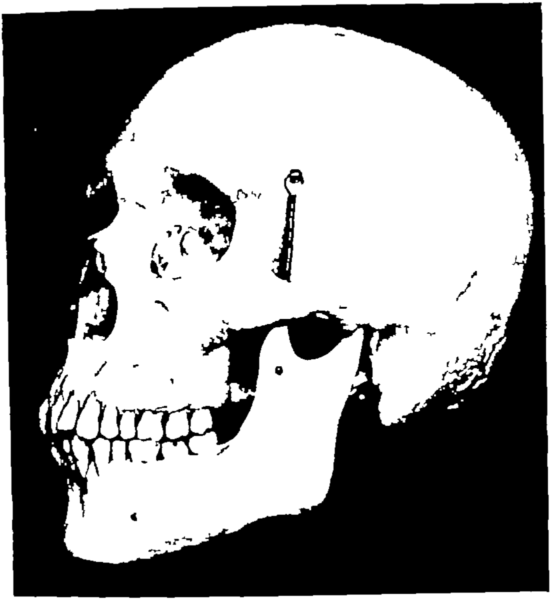

Fig 99 The skull showing the occlusion of the teeth

cles is upward forward and inward (Fig 100*B*)

MASSETER MUSCLE. The masseter an elevator of the jaw extends from the lower border of the zygomatic arch to the outer surface of the mandibular ramus and angle (Fig 100*A*) The direction of the deeper fibers is approximately vertical to the line of origin of the muscle.

TEMPORALIS MUSCLE. The fan-shaped temporalis muscle descends from the temporal fossa and inserts on the coronoid process mandibular notch and ramus of the mandible (Fig 100*C*) It is an elevator and retractor of the mandible.

INTERNAL PTERYGOID MUSCLE. The internal pterygoid originates within the pterygoid fossa of the sphenoid bone and is inserted on the inner surface of the ramus and angle of the mandible the muscle elevates the jaw and also plays an important role in the chewing or triturating movements. The direction of the pull is upward, inward and forward (Fig 100*D* *E*)

EXTERNAL PTERYGOID MUSCLE. The external pterygoid muscle originates from the infratemporal crest, the infratemporal surface of the greater wing of the sphenoid bone and the outer surface of the lateral pterygoid process it is inserted into the articular disk of the temporomandibular joint and into the neck of the condyle. The directions of muscle pull are inward forward and downward (Fig 100*D* *E*)

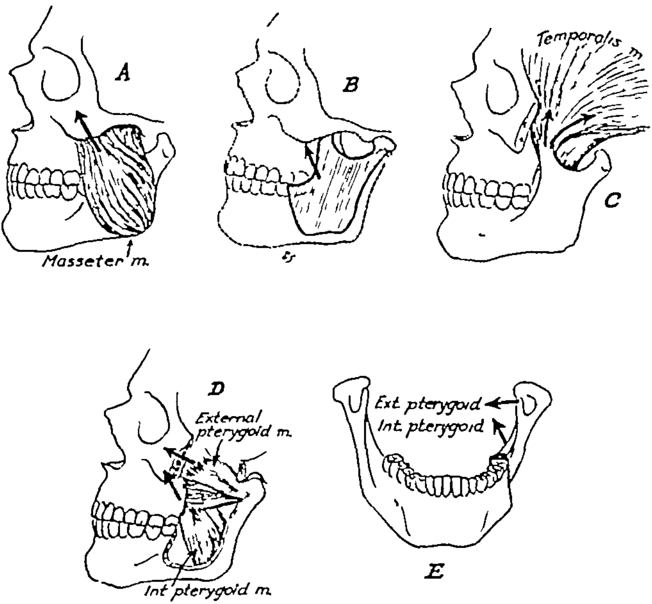

FIG 100

A. The masseter muscle
B. The arrows indicate the general upward and inward pull of elevator muscles.
C. The temporalis muscle
D. The external and internal pterygoid muscles.
E. Displacement due to pull of pterygoid muscles

Anterior Group

In fractures of the mandible the geniohyoid mylohyoid and digastric muscles (Fig 101*A* *B* *C*) tend to displace the anterior mandibular fragment downward and inward (Fig 101*D*)

THE GENIOHYOID MUSCLE. This muscle arises from the inferior mental spine and is inserted into the body of the hyoid bone (Fig 101*B*).

THE MYLOHYOID MUSCLE. Attached to the inner surface of the mandible along the internal oblique or mylohyoid line and extending to the hyoid bone to form the muscular floor of the mouth is the mylohyoid muscle (Fig 101*B* *E* *F*)

DIGASTRIC MUSCLE The anterior belly of the digastric muscle extends between the inner side of the lower border of the symphysis and a ligamentous attachment to the lateral cornu of the hyoid bone (Fig

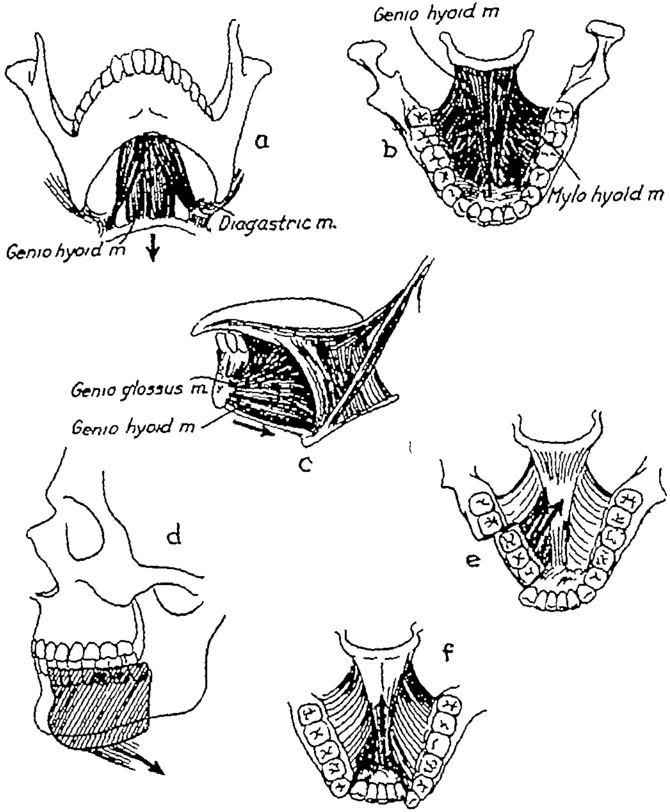

Fig 101 The suprahyoid muscles. Arrows indicate the direction of muscle pull and displacement of fragments in mandibular fracture

101A) The posterior belly of the muscle extends between the mastoid notch of the temporal bone and hyoid bone.

THE GENIOGLOSSUS MUSCLE. Originating from the superior mental spine on the inner surface of the body of the mandible is the genioglossus muscle It spreads out in fan like fashion and is inserted into the body of the tongue and the upper surface of the hyoid bone (Fig 101C)

The Temporomandibular Joint

The bony components of the temporomandibular joint (Fig 102) include temporal and mandibular surfaces. The upper bony portion is formed by the mandibular fossa and articular tubercle of the temporal bone; the lower is formed by the mandibular condyle Soft structures of the joint include a capsular ligament which is reinforced on its outer surface by fibers known as the temporomandibular ligament an articular disk or meniscus, synovial membranes above and below the intervening meniscus which secrete a lubricating fluid (synovial fluid) and the tendon of insertion of the external pterygoid muscle Movements of the mandibular condyle are controlled by the action of muscles which influences the hinge like rotating and gliding movements of the joint

Roentgen pictures of the joint disclose bony disorders such as fractures, displacements and abnormalities affecting the mandibular condyle

SURGICAL PATHOLOGY

Factors Influencing Displacement of Fragments

Displacement of fragments is influenced by the direction of muscle pull the direction and bevel of the fracture line the presence or absence of teeth the extent of

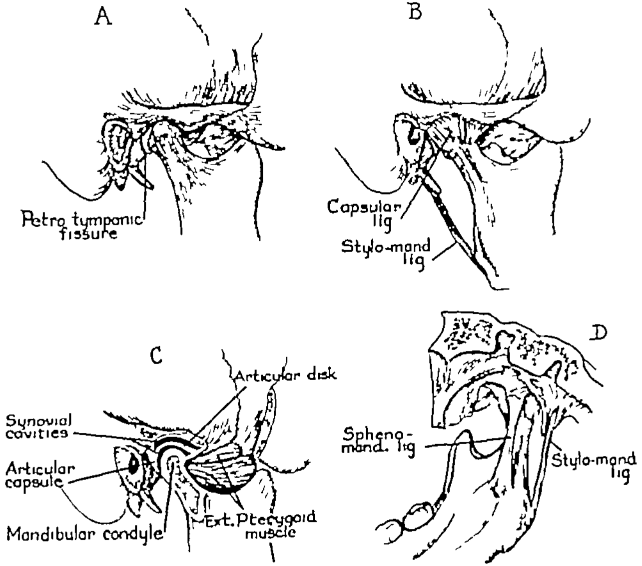

Fig 102 The temporomandibular joint

soft tissue wounds, and the direction and intensity of the traumatic force. The successful treatment of mandibular fractures involves an appreciation of all of these factors.

Direction of Muscle Pull

When the continuity of the jaw bone is interrupted by fracture, contraction of the musculature causes displacement of the fragments. The anterior muscle group exerts a backward and downward pull (Fig 101*D*) Although the anterior muscles are not as powerful as those of the posterior group, they influence the displacement of parts in a fracture of the body of the mandible particularly in multiple and comminuted fractures. The elevator muscles exert an upward and inward pull on the ramus (Fig 100*E*)

Direction and Bevel of the Fracture Line

When the line of fracture extends from the retromolar region diagonally downward and forward toward the symphysis (Fig 103*B* *D*) progressive displacement of the posterior fragment is not likely to occur for the position of the anterior fragment tends to prevent it. If however the line of fracture is in the opposite direction diagonally downward and backward contraction of the elevator muscles attached to the posterior fragment of the mandible causes displacement of the ramus (Fig 103*A* *C*) the displacement may be counteracted to some extent by the occlusion of the dentition on the side of the fracture

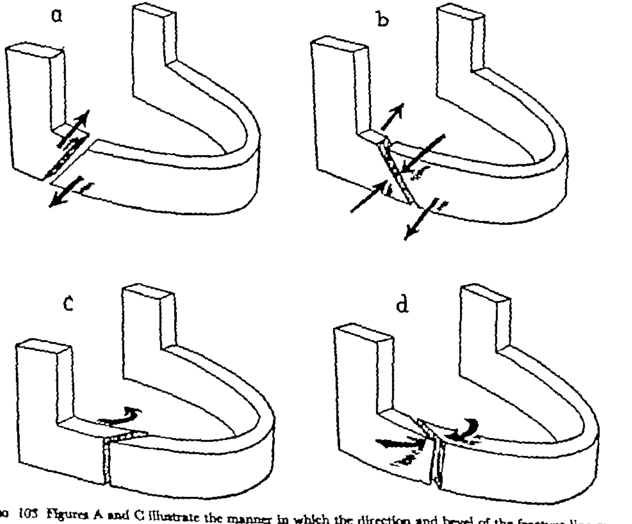

FIG 103 Figures A and C illustrate the manner in which the direction and bevel of the fracture line may favor displacement. Arrows indicate direction of muscle pull Figures B and D show how displacement may be prevented when the muscles pull the two fragments together (After W Kelsey Fry Shepherd, P R. McLeod, A. C. & Parfitt, G J The dental treatment of maxillo-facial injuries, 1942, Blackwell.

Presence or Absence of Teeth on the Fragment

Upward displacement is prevented when the lower teeth contact the teeth of the upper jaw. A single remaining tooth may often prevent displacement of a fragment (Fig. 101*A*); when the fragment is devoid of teeth, upward displacement is always enhanced (Fig. 101*B*).

Extent of Soft Tissue Wounds

In severely comminuted fractures with extensive laceration of soft tissues, the weight of the partially detached tissues may result in the downward displacement of an entire section of the mandible. This is exemplified in gunshot wounds where extensive laceration of the tissues surrounding the mandible often results in extreme displacement of the fragments. Displacement of the fragments is minimized when the soft tissue lacerations are sutured (Fig. 105).

Direction and Intensity of the Traumatic Force

When a blow striking the jaw lateral to the symphysis results in a fracture at the point of contact, an additional fracture may be produced in the region of the angle on the opposite side because of the compression of the mandibular arch (Fig. 106).

A direct blow on the symphysis may cause bilateral fracture, one fracture on each side of the resistant symphysis (Fig. 107). A blow on the symphysis from below may produce fracture of one or both of the mandibular condyles, through the neck of the condyle. The head of the condyle may be forced out of its socket or a segment of the comminuted mandible may be crushed inward in fractures caused by blows of sufficient force.

Injuries and Fractures of the Teeth

The teeth may be damaged in facial injuries, either in association with jaw fractures, or independent of them. The management of dental injuries is of particular interest in jaw fractures.

Anterior teeth are more exposed to injury than posterior teeth. Following trauma a tooth may be tender to touch and may be loose in its socket. Some teeth injured in this manner undergo spontaneous repair without becoming devitalized. A loose tooth requires support and should be fastened to

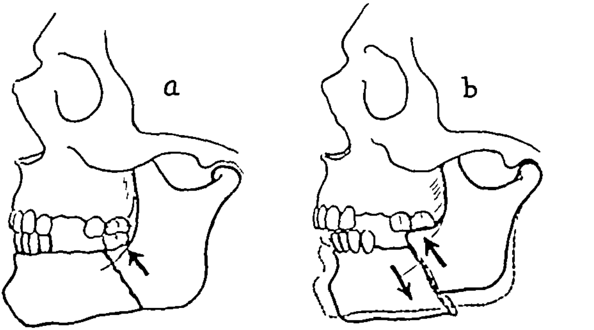

Fig. 101. A, Upward displacement may be prevented by the presence of teeth on the posterior fragment. B, Displacement of edentulous posterior fragment is favored due to the absence of teeth.

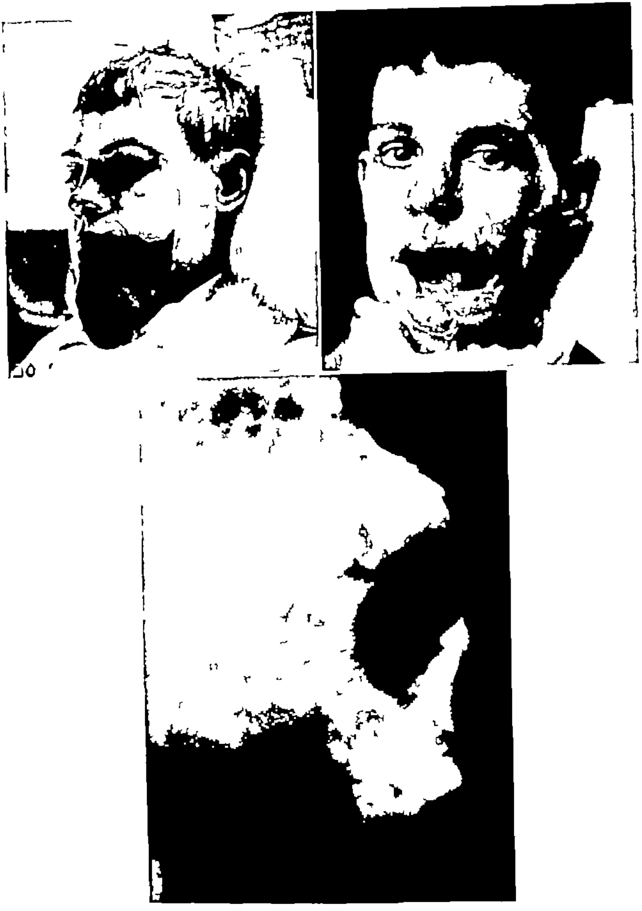

FIG. 105. (*Top left*) Extensive soft tissue wound of the left side of the face, corner of the mouth tongue, and lower lip There was comminution of the lower jaw involving the anterior section of the mandible. Several isolated fragments of bone were markedly displaced downward and backward (see *Bottom*)

(*Top right*) Appearance of the patient twelve days after admission to the hospital. At this date the fractured mandibular fragments were realigned and immobilized note the wound, greatly reduced in size following reduction and fixation of the fragments.

(*Bottom*) Roentgenogram of case shown in *Top left* The comminution of the lower jaw extended from the right mandibular angle to the left second bicuspid region, which was edentulous on that side. Anterior fragments of bone are displaced downward and backward toward the base of the tongue.

FIG. 106 Bilateral fracture of the mandible resulting from a blow on the right side of the jaw at a point lateral to the symphysis. There is an anterior fracture to the right of the symphysis and a posterior fracture in the left mandibular angle.

FIG. 107 Bilateral fracture of the body of an edentulous mandible resulting from a blow on the symphysis.

adjacent uninjured teeth by intradental wiring. The vitality of the dental pulp should be tested at intervals and the tooth either treated or removed if devitalized. Discoloration of the tooth is usually a sign of a devitalized pulp.

When multirooted teeth become loose a root or part of the crown has usually been fractured; such a tooth, if it cannot be salvaged, should be removed to prevent further complications.

A tooth is occasionally forced out of its socket without damage to surrounding alveolar tissues. This type of traumatic extrusion occurs more often in the upper anterior dento-alveolar segment. Reimplantation of such avulsed teeth has been attempted in the past, and although sometimes successful, it is at best a doubtful procedure. The exception to this rule occurs in the case of developing teeth because the root canals are wide, the blood supply to the root is abundant and regeneration of the torn tissues may occur.

EXAMINATION AND DIAGNOSIS

Clinical Examination

The signs of mandibular fracture vary according to the severity of the injury A linear fracture without displacement of the fragments produces few symptoms and little external swelling The dental occlusion appears normal on casual examination but the patient may complain that the teeth do not meet as before the accident and that pain is experienced when attempting to masticate. The following signs are revealed on close examination localized tenderness on pressure over the skin at the site of the fracture, localized ecchymosis on the buccal or lingual aspect of the mucosa covering the alveolar process, abnormal mobility between the teeth on each side of the fracture line and crepitus on mobilization of the fragments A break in the continuity of the mandible may injure the inferior alveolar nerve within the inferior alveolar canal fractures through the portion of the mandible extending from the inferior alveolar foramen and the mental foramen usually produce anesthesia of the lower lip on the affected side because of interruption of conduction to the mental nerve.

Other signs are noted in more extensive fractures such as marked swelling and edema in the sublingual or submaxillary regions and pain elicited by the slightest movement of the jaw Salivation appears to be increased for the patient drools abundantly being unable to control the flow of saliva or to swallow The change in contour of the lower portion of the face varies according to the extent of swelling and displacement of the fragments.

Although disturbance of the normal occlusion of the teeth is a positive sign of mandibular fracture further examination is necessary to locate the site of fracture and to determine whether the fracture is simple or comminuted. The type of displacement is an important determination Displacement may be horizontal with abnormal space and mobility between the teeth or vertical with one fragment of bone drawn upward in contact with the upper teeth while the other fragment is displaced downward. Overriding of fragments occurs in fractures in the region of the symphysis and at the angle of the jaw particularly in edentulous patients.

Fracture lines in the body of the mandible are rather easily determined occasionally however additional fractures in the ramus may be overlooked. When the fracture occurs on the side of the body of the mandible, as in the bicuspid region fracture in the subcondylar region of the opposite side should be suspected

Fragments of teeth or parts of artificial dentures may be embedded in the floor of the mouth, under the tongue or in the pharyngeal tissues. It is, therefore, important to examine these structures to detect possible puncture wounds.

Roentgenographic Examination

Although fracture of the mandible is often determined by clinical examination roentgenographic diagnosis (see Chapter 18) is necessary to obtain a more accurate picture of the direction and extent of the fracture and of the condition of the teeth. The roentgenogram reveals whether the fracture line involves the root apices, discloses previously existing dental abnormalities or pathological conditions of the bone shows the presence of foreign bodies and locates displaced fragments of bone and particles of teeth which may be scattered in various parts of the oral cavity The roentgenogram cannot be relied upon for the evaluation of consolidation of a mandibular fracture because newly formed callus is usually not visible in the x ray film Clinical testing by digital manipulation is the test for consolidation for this procedure indicates whether or not movement occurs in the line of fracture.

GENERAL PRINCIPLES OF TREATMENT

The importance of early reduction and immobilization of bone fragments cannot be overemphasized these procedures should be initiated as soon as the patient's condition permits. The advantages of early immobilization may be enumerated as follows

1 The fractured fragments of the mandible are manipulated and reduced freely before granulation tissue between the ends of the bone and the lacerated oral tissues has initiated the processes of repair

2. The reduction of displaced segments of bone reduces the size of the wound and restores anatomical relationships.

3 The elimination of pain resulting from motion between the ends of the fragments results in immediate comfort for the patient.

4 Early immobilization of fractured fragments promotes early healing of soft tissue and bone and diminishes the risk of ensuing infection and complications such as secondary hemorrhage

Anesthesia

Most patients with fractured mandibles can be treated under local or inferior alveolar block anesthesia particularly in those cases where treatment consists in reduction and immobilization by intermaxillary fixation For open reduction procedures it may be advisable to perform the operation under general anesthesia with intratracheal intubation by way of the nasopharyngeal airway

Occlusion of the Teeth as a Guide for Fracture Reduction

The fragments have usually been brought into correct alignment after the teeth have been immobilized in proper occlusion Any method of reduction should be based on this fact otherwise resulting deformities may affect the symmetry of the face and render the proper function of the teeth either difficult or impossible If an abnormal dental occlusion is suspected to have been present prior to the fracture careful examination of the occlusal surfaces of the teeth often reveals surfaces of wear indicating the habitual occlusion

Methods of Reduction

Reduction of the displaced fragments can be performed either immediately or progressively

Immediate Reduction

Reduction may be obtained immediately by replacing the fragments in alignment and in occlusion with the teeth of the maxilla and providing fixation of the parts with dental fixation appliances. Heavy sedation inferior alveolar block anesthesia or general anesthesia are usually required during this procedure

Progressive Reduction

The dentition of mandibular fragments may be brought into occlusal contact slowly and with little pain by means of steady traction with wires or by elastic bands extending between the fractured fragments and the upper jaw Reduction can be achieved in a few hours or may require continuous elastic traction for one or two days.

Mechanical Principles of Immobilization

In the treatment of the fractured mandible the teeth serve the role of abutments for fixation appliances. Sound teeth may be compared to pegs fastened to bone an ideal anchorage If the long bones bore knobs, or structures mechanically similar to teeth the orthopedic surgeon would surely make use of them Immobilization of fractured jaw fragments and fixation in correct dental relationships by means of interdental intermaxillary wiring was advocated by Gilmer in 1887 If the teeth are neither sound nor numerous the supporting alveolar processes may be utilized for anchorage

Modern techniques in anesthesia and the antibiotics have made possible the more frequent use of the direct surgical approach in the fixation of bony fragments in and around the oral cavity Direct interosseous wiring of fragments can be performed by exposing the fractured ends of the bone and maintaining the fragments in alignment with wire sutures. This method is employed in edentulous jaws and occasionally in those with teeth, in conjunction with intermaxillary fixation when possible

Immobilization can be obtained by external anchorage of the fragments the cranium is commonly employed for this purpose A headgear is made of suitable bandage material or plaster of Paris on a stockinette base and the intra-oral appliance is attached to it to achieve immobilization of the separated parts.

External fixation appliances, in which metal pins, fastened in the jaw bone serve as anchorage for external metal bars which retain the fragments in alignment, have also been employed in indicated cases.

Classification of Mandibular Fractures

Fractures of the mandible are variously classified by different authors. The most commonly used classification is based on the anatomic location of the fracture, such as fracture of the neck of the condyle, ramus body of the mandible or symphysis. This classification, however is of little assistance when considering methods of reduction and immobilization.

The following classification is based on the presence or absence of serviceable teeth in relation to the line of fracture because the teeth and their supporting structures serve as anchorage for intermaxillary fixation appliances. Three groups or classes of mandibular fractures are distinguished, each requiring a different method of treatment.

Class I Teeth Present on Both Sides of the Fracture Line (Fig 108A)

The teeth can be used as anchorage for the attachment of wire ligatures and for the retention of various types of fixation appliances irrespective of the location of the fracture even when only one serviceable tooth is present on each side. In these cases efficient immobilization may often be obtained without intermaxillary fixation

Class II Teeth Present on Only One Side of the Fracture Line (Fig 108B)

The teeth are utilized to fix the mandible to the maxilla. This type of fracture may occur in the neck of the condyle, the ramus, the angle or the body of the mandible.

Class III Fragments are Edentulous (Fig 108C)

The mandible may have been edentulous prior to fracture the teeth may have been destroyed at the time of the injury

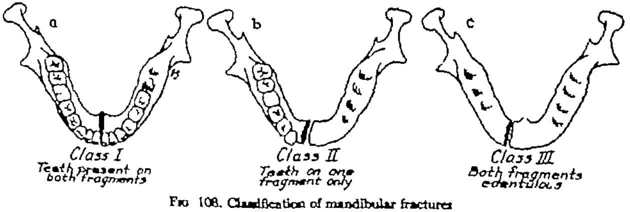

Fig 108. Classification of mandibular fractures

A—Class I fractures.
B—Class II fractures.
C—Class III fractures.

Treatment of Class I Fractures

Teeth Present on Both Sides of the Line of Fracture

Various types of Class I mandibular fractures include the simple type in which all or most of the teeth are present (Fig 109A) the type of fracture in which only one tooth remains on a posterior fragment (Fig 109B C) or the fracture which is associated with loss of bone where only one tooth is present on each fragment (Fig 109D)

The teeth on each side of the fractured area are usually sufficiently stable to act as anchorage for an appliance *Fixation by means of interdental wiring or dental appliances without intermaxillary fixation is advantageous for it immobilizes the fractured fragments but does not interfere with free movement of the mandible* an important factor in providing comfort for the patient. The basic principle of re-establishing normal dental occlusal relationships between the teeth of the fractured mandible and those of the maxilla as a guide to reduction must not be overlooked. While we stress the advantages of using

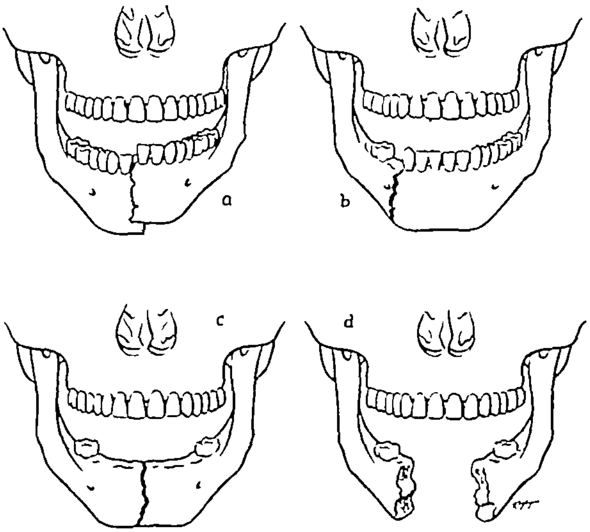

Fig 109 Class I fractures

A Simple fracture all the teeth are present on both fragment

B Fracture with only one tooth on the posterior fragment

C Fracture with only one tooth present on each fragment

D Fracture associated with loss of bone where only one tooth is present on each fragment In Class I fractures the teeth may be utilized as anchorage for splint

a dental appliance in Class I fractures in order to permit early release of intermaxillary fixation intermaxillary fixation is indicated and is usually maintained for at least a few days to assist in re-establishing satisfactory occlusal relationships. The principle of treating mandibular fractures without immobilizing the jaws by intermaxillary dental fixation was first advocated by Sauer (1889)

A number of simple methods afford the patient immediate comfort and relief. Some of these are considered emergency measures and may be performed under local anesthesia at the bedside or in the operating room.

HORIZONTAL OR LATERAL INTERDENTAL WIRING. In fractures with moderate displacement, when teeth are present the fragments are immobilized by stainless steel wire 30 gauge or brass wire 25 gauge passed around the necks of selected teeth and twisted together across the fracture line. This comparatively simple method, with various modifications, may be utilized as a means of immediate immobilization (Fig 110) Even overriding fractures are immobilized by employing the teeth on the overriding anterior fragment as a pulley to force the other fragment into position (Figs. 111 112) Teeth in the immediate proximity of the fracture line are not used since they are often weakened by the injury and may require removal to avoid future complications.

In delayed reduction when proper alignment of the fragments is not possible because of fibrous adhesions, the fragments should be loosened with an osteotome or a periosteal elevator under anesthesia before the interdental wires are twisted together

EMERGENCY DENTAL ARCH BARS. Prefabricated soft metal emergency dental arch bars are available for use in jaw fractures The most frequently employed in the United States are the Winter type arches (Fig 113) which may be molded to the dental arch and fastened to the teeth by direct wire fixation

CABLE ARCH WIRE. A strand of brass wire (0 020 gauge) fine gauge stainless steel wire, or chromium plated brass wire is passed about the neck of a molar tooth and twisted tightly The ends are left long, since this wire acts as a pivot for the following wires and must extend to the opposite molar (Fig 114*A*) Wires (0 030 gauge) are then

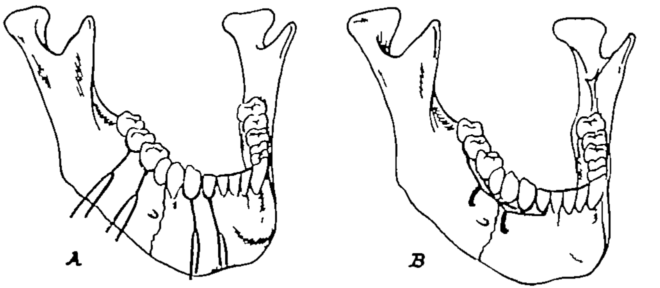

Fig 110 Horizontal wiring of mandibular fragments

A. In fractures with moderate displacement, wires may be anchored around selected teeth in the manner illustrated.

B. Wires are twisted together across the fracture line.

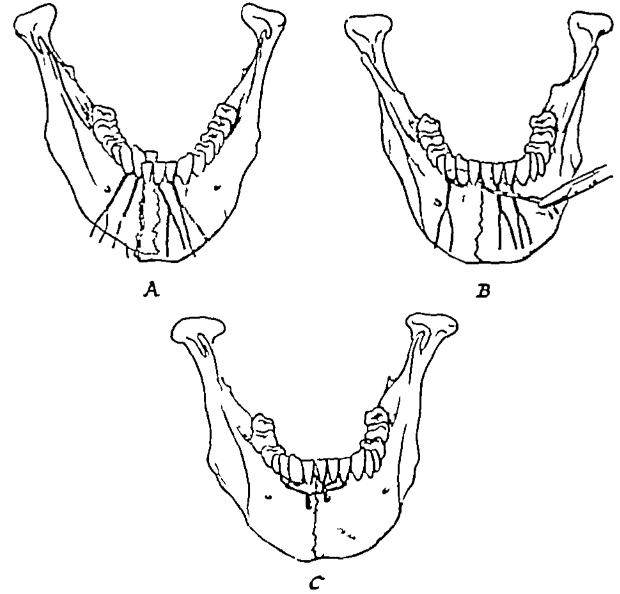

Fig. 111. Wiring of overriding fragments in mandibular fracture.

A. Wires are anchored to selected teeth on each side of the fracture.

B. Fracture reduced by using the teeth on the overriding fragment to force the other fragment into position.

C. Reduction completed by twisting the wires together across the fracture line.

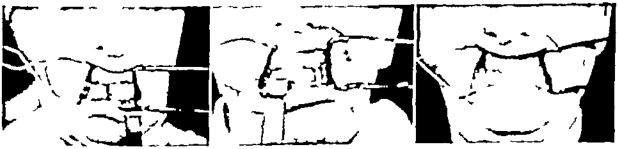

Fig. 11[illegible]. Mandibular fracture in which horizontal wiring was employed to reduce the fracture.

(Left) Fracture of mandible between the lower right central and lateral incisors with vertical displacement resulting from an automobile accident.

(Center) Horizontal wiring immobilizing the reduced fragment.

(Right) Appearance after healing of the fracture.

similarly anchored to the other teeth and each successively twisted about the pivot wire for four or five turns (Fig 114*B* *C* *D* *E*) This procedure is continued until a molar tooth on the opposite side is reached (Fig 114*F*)

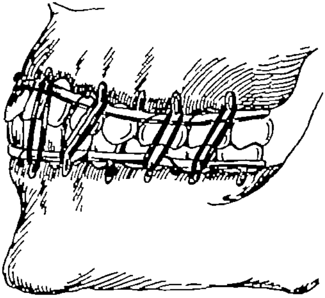

Fig 113 Winter arch. These arch wires are provided with prongs or bends which facilitate fixation with elastic bands or wires.

EMERGENCY BANDED DENTAL ARCH WIRE APPLIANCE. For many years, we have used a ready made Angle (1890) band which encircles the crown of the tooth and is held by means of a nut and bolt (Fig 115*A*) a wire soldered to the band serves as an arch bar (Fig 115*B*) The bar is made of 14 gauge annealed brass wire flattened to 19 gauge brass is used because of its malleability the contour is adapted to that of the dental arch by simply applying pressure with a suitable forceps. The arch bar is sufficiently rigid to maintain its shape under the traction of attached wires or elastics the flattened shape conforms to the contour of the teeth and increases stability The bar lies against the buccal and labial surfaces of the teeth and is fastened to them by means of wire ligatures (Fig 115*C*) Short metal spurs, for the attachment of

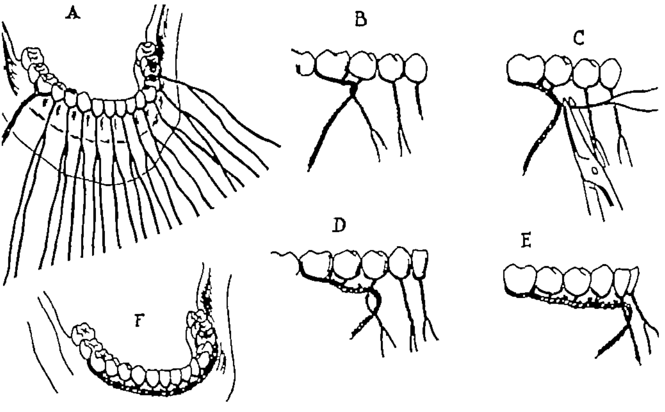

Fig 114 Technique of cable arch wire
A Wires are twisted around each tooth note the heavier wire around the molar tooth on the right side.
B, C, D and E. The heavy wire is twisted successively with each of the thinner wires.
F Cable arch wire completed.

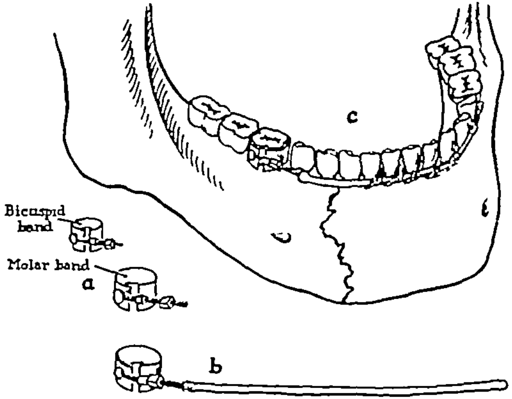

FIG. 115. Use of the banded arch wire splint in the reduction of mandibular fracture

A. Angle bands.

B. A wire is soldered to the band to serve as an arch bar

C. The teeth are attached to the bar with simple ligatures. These splints can be prefabricated and held in readiness for use.

elastic or wire ligatures are soldered to the arch bar if required.

DEFINITIVE BANDED RETENTION APPLIANCES. The methods of immobilization described above may be referred to as emergency techniques. If dental technical facilities are available, more precise types of appliances may be prepared to achieve stability and precision, especially in comminuted fractures. Custom made bands can also be prepared after a cast is made from impressions of the teeth. With careful and gentle techniques dental impressions may be taken in jaw fractures without causing the patient undue discomfort. For retention purposes, two adjacent teeth, when present, are banded and soldered together. Some of the bands are supplied with hooks on the buccal side for intermaxillary wiring; these can be utilized to anchor arch bars. Such appliances may also supply attachments for auxiliary soft tissue support. One of the most useful types, successfully employed for many years, is the banded retention appliance (Figs. 116 to 119), a practical application of the band and wire appliances employed by orthodontists. It consists of metal bands fitted around selected teeth and connected with heavy wire. This type of appliance not only assures fixation of the fragments but also permits lower jaw function. Additional advantages of such appliances are that they are less bulky and more hygienic than other appliances and minimize possible injury to gingival tissues. Accurate construction of such splints, however, requires the services of a trained technician and the facilities offered by a dental laboratory. When these facilities are available, such a definitive type of appliance can be constructed rapidly, thus providing the patient with reliable fixation

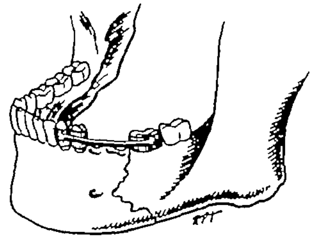

Fig 116. The retention splint in mandibular fracture. The bands are adjusted to the teeth and the arch wire is soldered to the bands, thus joining them

of the bone segments and also a means of attachment for a mold to support the injured soft tissues.

CAP SPLINTS Cap splints (Figs. 120 to 122) are designed to cover the occlusal surface and the exposed part of the teeth down to the gingival margins. They are indicated when a splint of unusual strength is required and can be either swaged or cast of German silver alloy and retained in place by cement. Satisfactory construction of such cap splints depends upon accurate casts of the teeth and strict attention to the occlusion. Cap splints are strong, re-

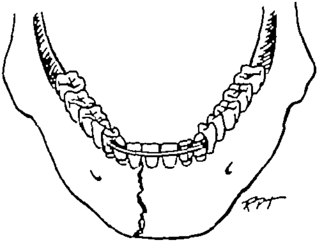

Fig 117 Example of retention splint for mandibular fracture.

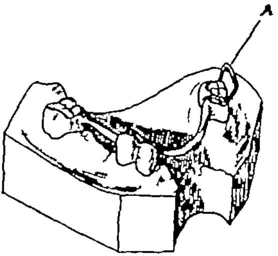

Fig 119 Example of a banded retention splint in a comminuted fracture, utilized to connect the remaining teeth and thus assemble various fragments. A. Shows a wire flange used as a bite-guide

Fig 118. Roentgenogram showing a retention splint holding a posterior fragment. This case also demonstrates the utilization of one remaining tooth in the posterior fragment to prevent the forward and upward displacement of the posterior fragment.

sistant and well anchored and are particularly useful in fractures of the mandible when teeth are present. The ease and speed with which such splints can be applied renders them especially adaptable in emergencies. One cannot, however, be certain of the occlusion when the occlusal surfaces of the teeth are covered. When these cap splints are removed, discrepancy of occlusion must be corrected by grinding the cusps of the teeth. For this reason the authors usually prefer to use appliances that do not extend over the occlusal surface of the teeth.

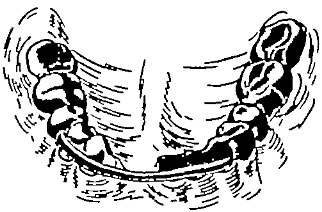

FIG. 170. A swaged cap splint, cemented to the teeth on both sides of the fracture. The two halves of the splint are joined by a wire arch.

SECTIONAL APPLIANCES. In multiple fractures of the lower jaw associated with dis

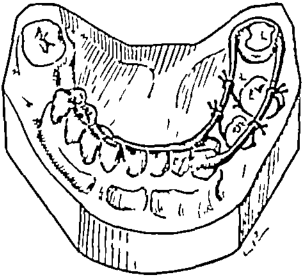

FIG. 172. Diagram showing reduction of a mandibular fracture by a cap splint on the main fragment and a metal band on the tooth on the other side. On the left side wire ligatures anchored to the teeth and to the arch wire serve to reduce a displaced intermediary fragment.

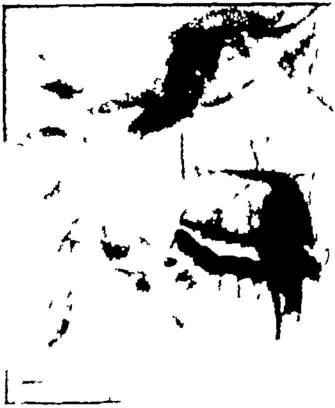

FIG. 171. Roentgenogram of fractured mandible immobilized by means of a cap splint.

placement of fragments, it is often advisable to construct the fixation appliances in sections, assembling them in the oral cavity. Modifications of this type of appliance can be used to advantage. They are made of bands over selected teeth fitted to teeth on each fragment similar to techniques employed in orthodontics. When considerable stress must be imposed upon the bands, it is advisable to band adjacent teeth welding the bands together (Fig 123) thus increasing retention (Shapiro 1957). Horizontally placed tubes and hooks are soldered to the outer surface of the bands, the hooks being employed for intermaxillary fixation. The arch bar after being contoured to a suitable curvature is passed into the tubes and wired to the teeth.

A sectional fixation appliance with removable lock bar is shown in Figure 124.

A simple type of sectional appliance is shown in Figure 125. In this appliance corrugated arch wires are soldered to bands or caps and the two ends of the arch bar pass each other in the mid line; these are then fastened together with fine stainless steel wire. Another type of sectional appliance

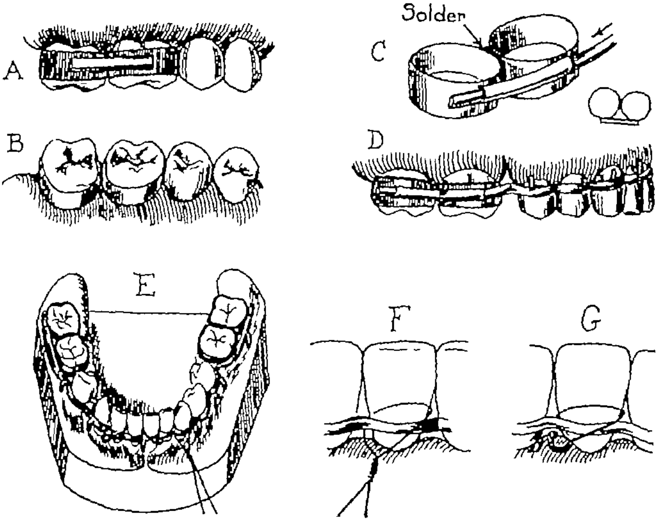

Fig. 123 Definitive banded retention appliance (Shapiro)

A and B. Orthodontic type bands are fitted to two adjacent teeth.

C. The bands are welded together by solder; the horizontal tube is also soldered to the buccal surface of the bands.

D. An arch-bar is fitted to the outer contour of the teeth, the ends are slipped through the buccal tubes and the bar is wired to selected teeth.

E. Banded retention appliance on plaster cast ready to be fitted to the patient's dentition. The arch wire is further fixed to the teeth by means of wire ligatures.

sistant and well anchored and are particularly useful in fractures of the mandible when teeth are present. The ease and speed with which such splints can be applied renders them especially adaptable in emergencies. One cannot however be certain of the occlusion when the occlusal surfaces of the teeth are covered. When these cap splints are removed discrepancy of occlusion must be corrected by grinding the cusps of the teeth. For this reason the authors usually prefer to use appliances that do not extend over the occlusal surface of the teeth.

SECTIONAL APPLIANCES. In multiple fractures of the lower jaw associated with dis-

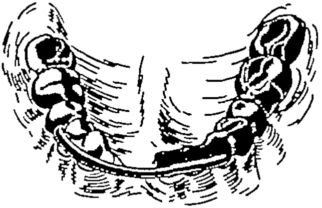

FIG. 120. A swaged cap splint, cemented to the teeth on both sides of the fracture. The two halves of the splint are joined by a wire arch.

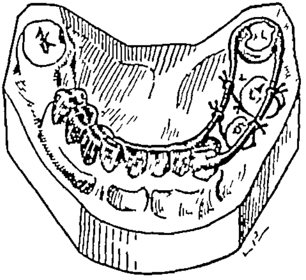

FIG. 122. Diagram showing reduction of a mandibular fracture by a cap splint on the main fragment and a metal band on the tooth on the other side. On the left side wire ligatures anchored to the teeth and to the arch wire serve to reduce a displaced intermediary fragment.

FIG. 121. Roentgenogram of fractured mandible immobilized by means of a cap splint.

placement of fragments, it is often advisable to construct the fixation appliances in sections assembling them in the oral cavity Modifications of this type of appliance can be used to advantage. They are made of bands over selected teeth fitted to teeth on each fragment similar to techniques employed in orthodontics When considerable stress must be imposed upon the bands, it is advisable to band adjacent teeth welding the bands together (Fig 123) thus increasing retention (Shapiro, 1957) Horizontally placed tubes and hooks are soldered to the outer surface of the bands, the hooks being employed for intermaxillary fixation. The arch bar after being contoured to a suitable curvature, is passed into the tubes and wired to the teeth.

A sectional fixation appliance with removable lock bar is shown in Figure 124

A simple type of sectional appliance is shown in Figure 125 In this appliance corrugated arch wires are soldered to bands or caps and the two ends of the arch bar pass each other in the mid line these are then fastened together with fine stainless steel wire. Another type of sectional appliance

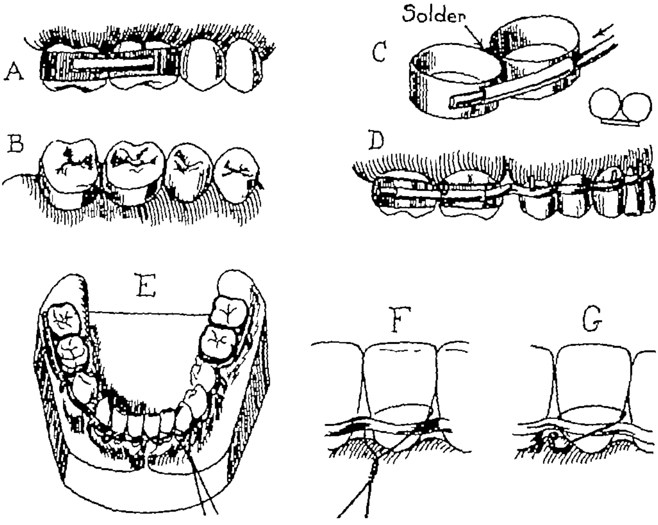

FIG 123 Definitive banded retention appliance (Shapiro)

A and B Orthodontic type bands are fitted to two adjacent teeth.

C. The bands are welded together by solder the horizontal tube is also soldered to the buccal surface of the bands.

D An arch-bar is fitted to the outer contour of the teeth, the ends are slipped through the buccal tubes and the bar is wired to selected teeth.

E. Banded retention appliance on plaster cast ready to be fitted to the patient's dentition. The arch wire is further fixed to the teeth by means of wire ligatures

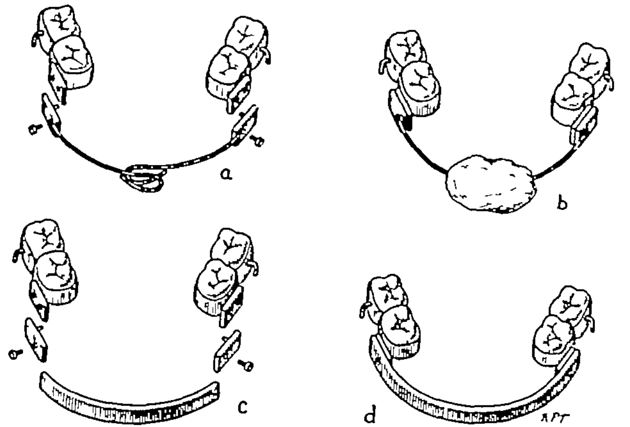

Fig. 124 Type of sectional splint used in case shown in Figures 127 and 128

A. Bands or caps are cemented to abutment teeth Metal plates have been soldered to the outer surface of the bands. Adaptable arch wires are soldered to additional plates arranged in such a way that they may be bolted to the plates on the bands.

B. Fragments are manipulated to attain occlusion of the mandibular teeth with the opposing teeth of the upper jaw and the wires are joined in the mid-line with dental compound or plaster

C, D The adaptable arch wire is replaced by a solid bar and the various parts of the sectional splint are assembled

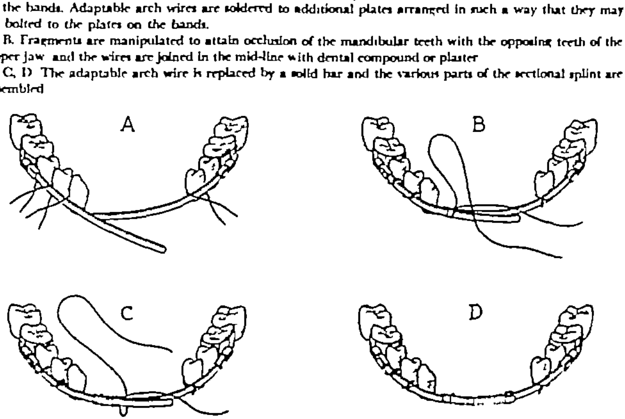

Fig. 125 Sectional arch wire splint fastened by central wiring

A The arch wire splints are anchored by a band to the first molar on each side and by wire ligatures to the other teeth

B After the fragments are manipulated into position establishing occlusion with the upper teeth, the two corrugated arch wires are joined together by a fine stainless steel wire ligature Note the method of applying the wire ligature

C and D Wire ligature fixation of the arch wires

particularly useful in the delayed reduction of mandibular fractures is shown in Figure 126

In the early treatment of fractures, while manipulation of the fragments is still possible it is rarely necessary to construct complicated fixation appliances. In neglected fractures with soft tissue adhesions around displaced fragments, it is better to incise through the adhesions and assemble the bone fragments (Figs. 127 128) rather than to employ slower methods of reduction

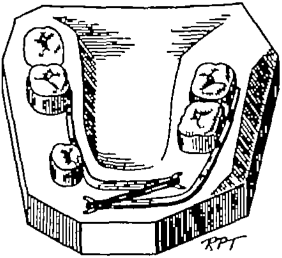

Fig 126. Sectional splint employing a band and arch wire. A prong at the end of the arch wire serves as a means of attachment for elastic bands, for the purpose of expanding the overriding fragments.

EXTERNAL SKELETAL FIXATION APPLIANCES. Extra-oral appliances are either external skeletal fixation appliances with single or Roger Anderson twin pins, or Kirschner wires which are passed through the body of the mandible. Whatever merit such methods have in other types of fractures, the authors are convinced that there is little justification for the application of such extra-oral methods in Class I fractures when sound teeth are present on either side of the fractured area

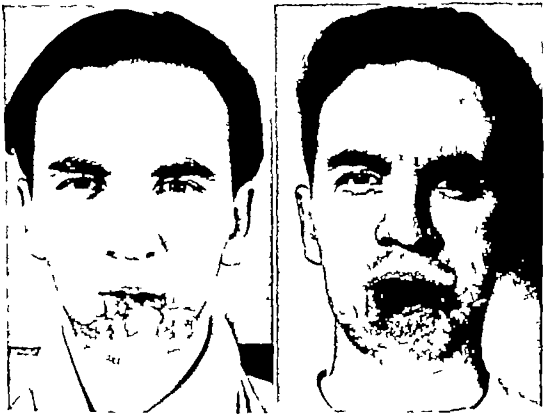

Fig 127

(*Left*) Photograph of a sailor who sustained a compound comminuted fracture with loss of bone as a result of bomb injury showing neglected fracture with soft tissue adhesions and medial displacement of the fragments.

(*Right*) Adhesions incised and fragments reduced by surgical measures before splint was applied See completed case (Fig 1019)

(J M Converse J Oral Surg 3 112, 1945)

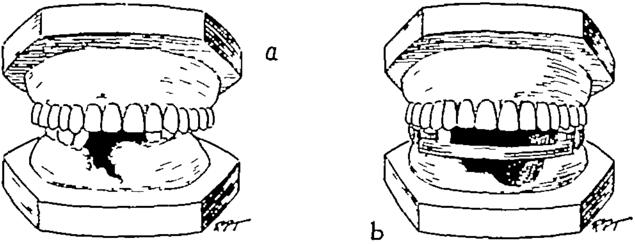

Fig 128

A. A drawing of the cast made from an impression of the patient shown in Figure 127

B. The type of splint, illustrated in Figure 124 employed to maintain the fragments in correct occlusal relationship (see Fig 1019)

APPLIANCES FOR COMPOUND COMMINUTED FRACTURES. A comminuted fracture includes multiple radiating lines of fracture Such comminuted fractures are compound being associated with an external wound or an intra-oral soft tissue wound due to the tearing of the oral mucoperiosteum The multiple fragments are exceedingly mobile and rarely tend to interlock rigidly The *pronounced displacement of the bone segments* may be increased by the weight of lacerated overlying flaps of soft tissue

The extensive mobility of the fragments in such fractures of the mandible poses problems that are not encountered in other types of fractures. Because of their looseness it is often a relatively simple task to replace the displaced fragments in the desired position if the procedure is initiated soon after the fracture occurs.

Some compound comminuted fractures require special methods of treatment these include fractures associated with extensive comminution of the anterior portion of the body of the mandible with displacement of the anterior fragments, and in some cases, loss of bone lip and chin When comminution of the bone is associated with large wounds of the lip chin and oral mucosa and includes destruction of anterior teeth and alveolar bone provision should be made to immobilize the fragments and also to support the soft tissues to prevent undue contractures and adhesions over the alveolar process. Such contractures destroy the buccal sulcus and prevent subsequent adaptation of suitable prostheses. The loss of alveolar bone and teeth also deprives the lower lip of its normal support

The type of appliance to be employed *must immobilize the bone fragments and* lend support to the injured soft tissues. The damaged teeth and isolated fragments of alveolar bone must usually be removed in such cases and the lacerated mucoperiosteum and lip tissues sutured

An appliance designed to maintain an acrylic mold minimizing subsequent deformity is illustrated in Figure 129 It consists of a dental arch bar appliance which is fastened to the remaining teeth on each side of the fracture A perpendicular bar is soldered at right angles to the arch wire forming a T attachment A removal acrylic mold is constructed to fit the arch bar its T attachment and the alveolar process the mold maintains normal contour of the lip and also prevents adhesions of the soft tissues.

In order to insure correct dental occlusal relationships, a loop of wire is soldered to the buccal surface of the molar band

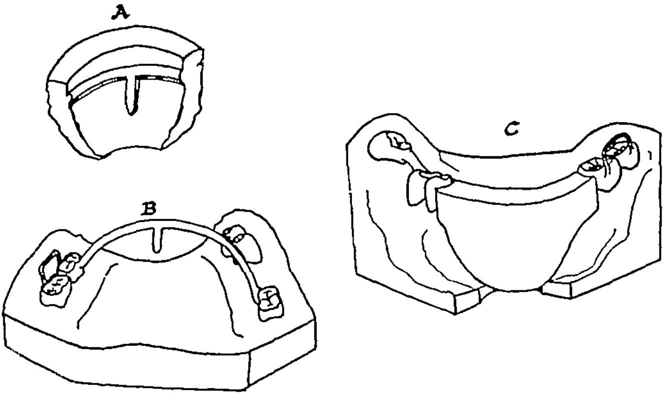

Fig. 129 Diagrammatic drawings of a band and wire splint with a perpendicular wire or "T" extending from the arch wire (B) An acrylic restoration of the missing structures is molded over the arch wire, with sufficient bulk to prevent tissue contraction (A C) At a later stage this acts as a supporting aid during the reconstruction of the soft tissues.

to act as an occlusal guide or flange. Modifications of such an appliance have been described in the literature of the first World War and later by Fry Shepherd, McLeod and Parfitt (1942) Fry and his colleagues prefer a screw attachment to anchor the mold to the splint. The T attachment is a fairly simple apparatus to construct and retains the mold firmly the grooves of the mold however must fit the T-bar accurately

It is not unusual in some cases of comminuted fractures, for small fragments of bone to be located between the main segments of the mandible, entirely displaced from their normal alignment (Fig 130) If these isolated fragments are immobilized and connected with the main segment, they eventually consolidate It is important to be aware of the necessity for preserving fragments which may aid in the regeneration of a new bony arch The fragments are raised to their approximate anatomical position after drilling holes through them and suspending them to the arch bar with

Fig 130 Roentgenogram of a compound, comminuted mandibular fracture associated with soft tissue wounds, showing extreme displacement of numerous fragments.

fine wires (Figs. 131, 132). This procedure may appear drastic in these injuries, however, the upper surfaces of the bone fragments are often exposed through the surrounding soft tissues. It is therefore possible to grasp each particle of bone gently *with a forceps and to drill a hole through* it without injuring the tissues.

LOSS OF ANTERIOR BONE SEGMENTS ASSOCIATED WITH LOSS OF SOFT TISSUES OF THE LIP AND CHIN. This type of injury, characteristic of a gunshot wound of the jaw, requires special consideration. It includes extensive laceration, even loss of the lip and chin, combined with loss of the middle portion of the mandible (Fig. 133). Because this type of condition comprises such a distinct class, it seems appropriate to describe the treatment in detail.

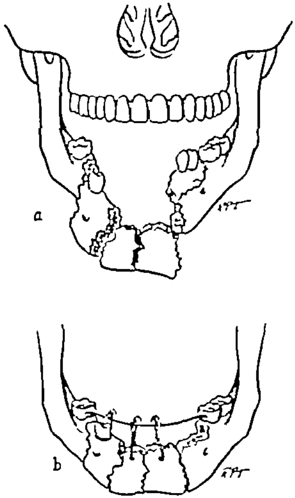

Fig. 131. Diagrams illustrating a method of reduction in mandibular fractures with extreme displacement of fragments.

A. The type of fracture.

B. Fragments suspended from an arch wire attached to bands on posterior teeth.

Fig. 132. Roentgenogram showing fragments suspended from an arch wire in the case shown in Figure 131.

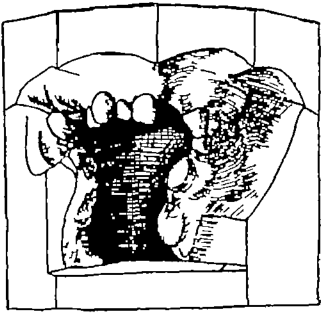

FIG. 133. (*Left*) Drawing of plaster casts showing complete loss of the anterior part of the mandible (*Right*) Photograph of a typical case showing extensive destruction of the soft tissues of the lower part of the face, with loss of the mandible anterior to the second molar regions. Later a splint (shown in Fig 134) was made prior to operative treatment for reconstruction of the lower half of the face

The early treatment should be planned with a view to future surgical reconstruction for these patients are eventually submitted to extensive reconstructive procedures. Although the external wounds are extensive sufficient mandibular bone usually remains to serve as a foundation for future reconstruction. The bony fragments may include a part of the body of the mandible on each side with or without teeth or in cases with extensive loss of bone, may consist only of the exposed stumps of the ascending rami

Utilization of the remaining parts of the mandible is essential in reconstruction Unless these bony segments are carefully immobilized at the earliest possible moment displacement complicates future plastic surgical procedures. The fragments of bone are loose and easily manipulated in the early stage. The teeth on each fragment are connected by a cap or banded appliance with a solid intermediary bar to insure immobilization A vertical wire forming a T is soldered to the bar in the median line (Fig 134) The appliance is cemented in position maintaining the isolated fragments as one unit. If only a single tooth is present on each side, it is advisable to use an Angle band tightened around the tooth with screws rather than to cement it such a band seems to retain its position firmly (Fig 135)

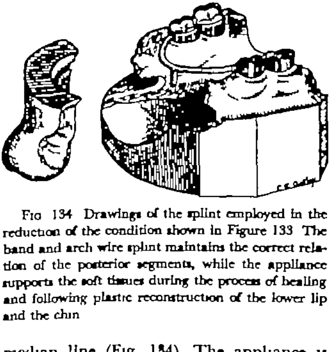

FIG 134 Drawings of the splint employed in the reduction of the condition shown in Figure 133 The band and arch wire splint maintains the correct relation of the posterior segments, while the appliance supports the soft tissues during the process of healing and following plastic reconstruction of the lower lip and the chin

Figure 156 shows a type of removable support useful in the early stages of reconstruction to control the overflow of saliva to preserve the buccal sulcus between the cheek and the remaining portions of the alveolar process of the mandible to support the remaining soft tissues *of the lips, to form a framework when* plastic surgery for the reconstruction of the lip is performed and to act as a carrier if a skin graft *is required to reconstruct the* sulcus (Fig 157)

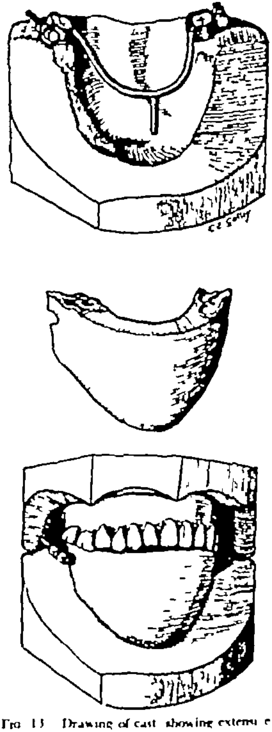

Fig 156 Drawing of cast showing extensive loss of the mandible with one molar tooth remaining on each posterior segment A band and wire splint is used to control the position and function of the rami In this case the bands instead of being cemented to the teeth are tightened with screws to achieve greater security *The removable acrylic mold is of a size and shape to maintain the contour of the remaining soft* tissues of the face

Treatment of Class II Fractures

Teeth Are Present on Only One Side of the Line of Fracture

In this second class of fracture sound teeth are present on only one side the fracture may be located in any part of *the body of the mandible (Fig 158). These* fractures include a wide variety in which the edentulous portion of the mandible is *often difficult to control. Problems of im*mobilization vary according to whether the angle and bevel of the fracture line oppose or favor displacement of the fragments.

Fractures in which the Angle of the Fracture Line Resists Displacement

Fractures in which the bony contact of the fractured surface is at an angle which resists the muscle pull do not tend to be displaced upward by the pull of the elevator muscles of the jaw (Fig 159) Such fracture sites include the body of the mandible or the angle of the jaw the fracture line extending from the alveolar crest downward and forward toward the lower border of the bone *Simple immobilization* of the undisplaced fragments is usually obtained by intermaxillary fixation of the *teeth in correct occlusal relationship.* A number of procedures to achieve such fixation include simple intermaxillary wiring *the eyelet method of wiring* intermaxillary multiple loop wiring, wire hooks or buttons, banded intra-oral arch bar appliances, or direct intra-osseous wiring

SIMPLE INTERMAXILLARY WIRING. This is one of the most widely used and effective methods of immobilization Interdental wires are passed between the teeth and

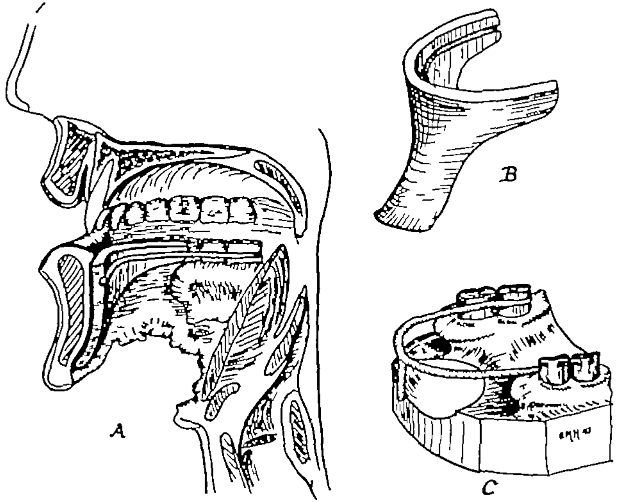

Fig 136. Diagrammatic drawing illustrating the type of band and wire splint used to maintain the remaining posterior fragments of the mandible in their normal position while an acrylic support, being concave at its lower end, acts as a seat to support the lower lip and chin and prevents undue contracture. In the absence of bony framework, such supports are essential to prevent gross deformities.

A. Acrylic support in compound fracture with loss of tissue. B Acrylic mold C. T-shaped splint.

(V H Kazanjian Surgery 15:22 1944)

Fig 137 (*Left*) Photograph showing destruction of the mandible anterior to the second molar teeth, resulting from gunshot wound involving the lip and submandibular tissues.

(*Right*) Photograph of the patient following the insertion of the prosthesis as shown in Figure 136, and late primary suture.

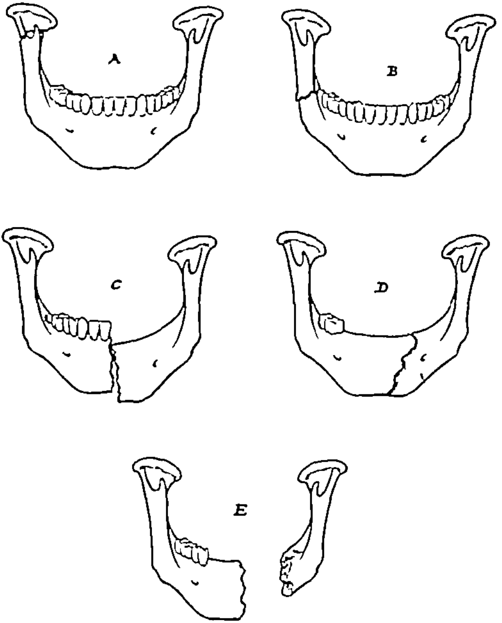

Fig. 138 Diagrams of various types of fractures of the mandible with serviceable teeth on only one side of the fracture line. The site of fracture may be at the condyle neck, the ramus, the angle of the jaw or any part of the body of the mandible on the edentulous side.

Fig. 139 Roentgenogram showing the fracture line extending from the alveolar ridge downward and forward toward the lower border. The slant of the fracture line resists displacement of the post fragment

twisted around the necks of selected teeth of the upper and lower jaws (Fig 140). The wires are then twisted together bringing the teeth into occlusion to produce intermaxillary fixation as illustrated in Figure 140. Bicuspid and molar teeth may be wired singly or doubly but incisors should be wired together in pairs when feasible. It is not necessary to utilize many teeth in a single simple fracture in the molar region ... llary wiring of up- ... nd lo ... for example is ... Ivy

wire six inches long, 24 gauge for posterior teeth, and 22 gauge for anteriors is bent midway of its length and twisted around an instrument to form an eyelet (Fig 141)

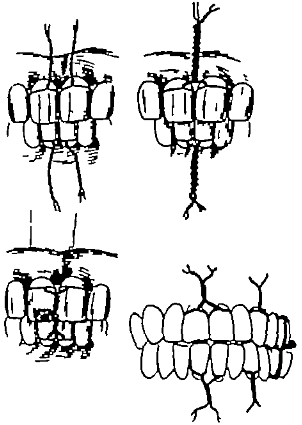

Fig. 140 Diagrams showing interdental or intermaxillary wiring Wires passed and twisted around necks of teeth, upper as well as lower and then fastened together Bicuspids and molars are wired singly but incisors and cuspids should be fastened together in pairs, as in the diagram, then attached to the corresponding teeth of the opposite jaw (V H. Kazanjian, J Am Dent. A. 20 758 1933)

After selecting the teeth to be wired both ends of the eyelet wire are inserted through the interdental space from the outer surfaces of the teeth. One end is drawn around the anterior tooth, the other around the posterior tooth the ends are then twisted together In the upper jaw the eyelets should project above and in the lower jaw below the horizontal twist this prevents the ends from impinging on each other The ends of the wire are cut and bent to prevent irritation of the lip or cheek. A number of teeth on each side of the jaw are prepared in this manner and the opposing eyelets are connected by passing a third wire through them and twisting it to draw the teeth of both jaws together or attaching orthodontic type rubber bands to the eyelet and the twisted end of wire The upper and lower eyelets should provide leverage to aid in aproximating the fragments and to restore occlusal harmony

INTERMAXILLARY MULTIPLE LOOP WIRING (Stout, 1912) This method requires the presence of at least three adjacent teeth (Fig 142) The wires form a number of loops along the buccal side of the alveolar process, and are especially applicable when elastic bands are used for traction The wire is passed through the interdental space between the second and third molars. The buccal portion of the wire is placed

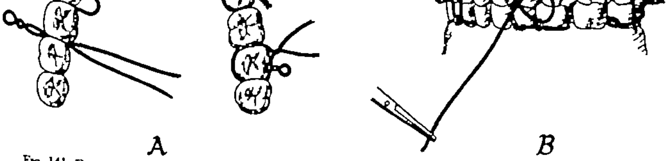

Fig 141 Diagrams of eyelet method showing various steps in constructing eyelets and joining upper and lower jaws together (After Ivy)

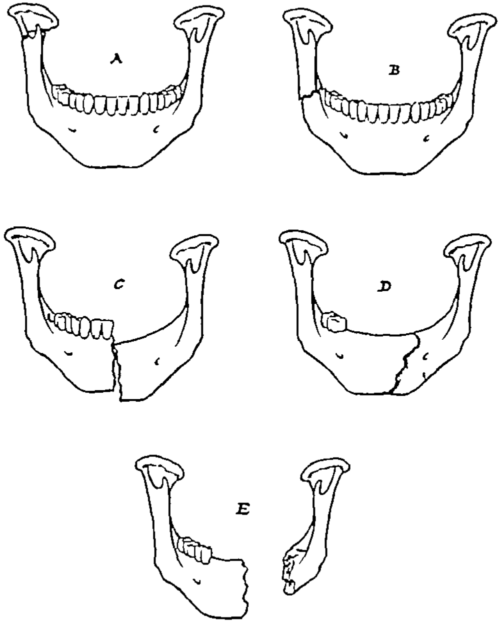

Fig 138. Diagrams of various types of fractures of the mandible with serviceable teeth on only one side of the fracture line The site of fracture may be at the condyle neck, the ramus, the angle of the jaw or any part of the body of the mandible on the edentulous side

Fig 139 Roentgenogram showing the fracture line extending from the alveolar ridge downward and forward toward the lower border The slant of the fracture line resists displacement of the posterior fragment

twisted around the necks of selected teeth of the upper and lower jaws (Fig 140). The wires are then twisted together bringing the teeth into occlusion to produce intermaxillary fixation as illustrated in Figure 140 Bicuspid and molar teeth may be wired singly or doubly but incisors should be wired together in pairs when feasible It is not necessary to utilize many teeth in a single simple fracture in the molar region intermaxillary wiring of upper and lower bicuspids, for example is usually sufficient

EYELET METHOD (Eby 1920 Ivy 1922) A

wire six inches long, 24 gauge for posterior teeth, and 22 gauge for anteriors, is bent midway of its length and twisted around an instrument to form an eyelet (Fig 141)

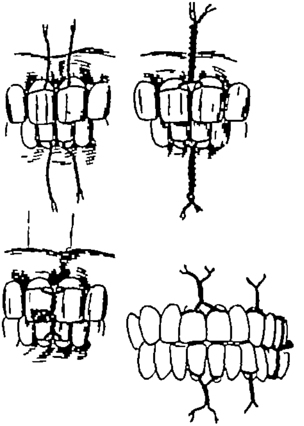

FIG. 140 Diagrams showing interdental or intermaxillary wiring Wires passed and twisted around necks of teeth, upper as well as lower and then fastened together Bicuspids and molars are wired singly but incisors and cuspids should be fastened together in pairs, as in the diagram then attached to the corresponding teeth of the opposite jaw
(V H. Kazanjian J Am Dent. A., 20 758, 1933)

After selecting the teeth to be wired both ends of the eyelet wire are inserted through the interdental space from the outer surfaces of the teeth One end is drawn around the anterior tooth the other around the posterior tooth the ends are then twisted together In the upper jaw the eyelets should project above and in the lower jaw below the horizontal twist this prevents the ends from impinging on each other The ends of the wire are cut and bent to prevent irritation of the lip or cheek. A number of teeth on each side of the jaw are prepared in this manner and the opposing eyelets are connected by passing a third wire through them and twisting it to draw the teeth of both jaws together or attaching orthodontic type rubber bands to the eyelet and the twisted end of wire. The upper and lower eyelets should provide leverage to aid in aproximating the fragments and to restore occlusal harmony

INTERMAXILLARY MULTIPLE LOOP WIRING (Stout 1942) This method requires the presence of at least three adjacent teeth (Fig 142) The wires form a number of loops along the buccal side of the alveolar process, and are especially applicable when elastic bands are used for traction The wire is passed through the interdental space between the second and third molars. The buccal portion of the wire is placed

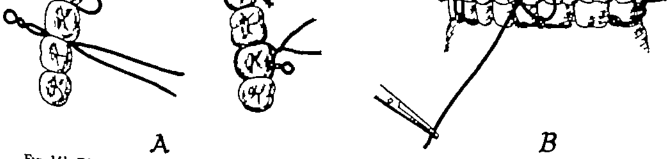

FIG 141 Diagrams of eyelet method showing various steps in constructing eyelets and joining upper and lower jaws together (After Ivy)

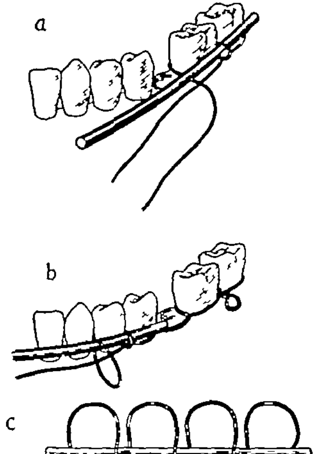

Fig. 142 Diagrams illustrating intermaxillary multiple loop wiring (After Stout.)

against the gingival margins of the teeth selected for wiring and a lead or soft metal bar about 3 mm in diameter is placed beside this wire The lingual portion of the wire is passed through each interdental space in turn forming a loop over the bar and buccal portion of the wire and is then returned lingually through the same interdental space. When the required number of teeth have been wired the ends of the buccal and lingual portions of the wire are twisted together in either the bicuspid or cuspid region. The lead bar is then removed leaving a series of loops on the buccal side. Each loop is twisted twice and bent to form a hook. If a tooth is missing, the buccal and lingual arms of the wire are twisted to bridge the space and the looping process is continued

THE KAZANJIAN BUTTON This method is particularly adaptable for immobilization by intermaxillary elastics, but should be considered a temporary method except in simple types of fractures in which the position of the fragments need not be modified (Fig 143). Usually two teeth are utilized to support the button. A wire is passed around the neck of each tooth and twisted (Fig 143*A*) The two twisted wires are then retwisted and cut about one inch from the teeth (Fig 143*B*). The remaining ends of the wire are then shaped into a small button (Fig 143*C*) Bicuspid teeth or a bicuspid and a molar tooth form substantial anchorages for the button

If anterior teeth are selected 28 gauge stainless steel wire should be used in preference to brass wire for it forms a smaller loop non irritating to the lips. The upper and lower anterior teeth should be wired in pairs for additional strength as described for intermaxillary wiring All four mandibular incisors should be joined.

BANDED ARCH WIRE APPLIANCE. Dental appliances which provide facilities for attaching intermaxillary elastics or wires can be employed as anchorage if a sufficient number of teeth are not available for interdental wiring Metal bands or caps are fitted and cemented to selected teeth and connected with an arch bar (see Fig 123). Another type of arch bar is soldered to Angle bands fitted to the upper and lower teeth and utilized as shown in Figure 141

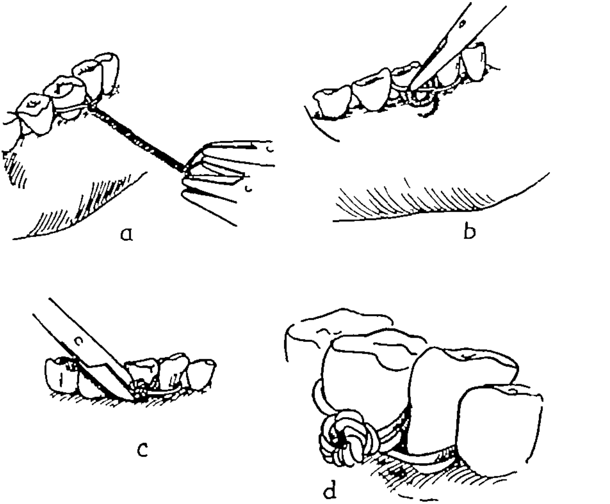

FIG 143 Diagram showing various steps in the formation of the Kazanjian button (From P D Wilson *Management of Fractures and Dislocations* J B. Lippincott Co., 1938)

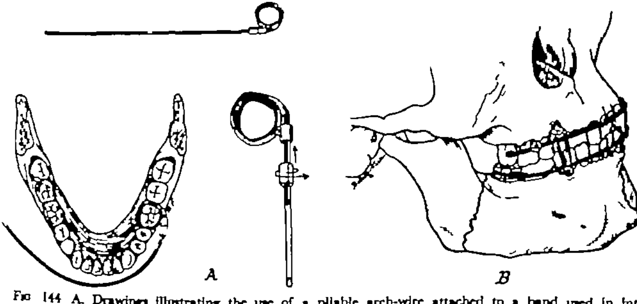

FIG 144 A. Drawings illustrating the use of a pliable arch-wire attached to a band used in inter maxillary wiring

B. Band and bar splint applied to the upper and lower teeth.

(V H Kazanjian and M. S Strock J Am. Dent. A. 29 79 1942)

Fractures in which the Angle of the Fracture Line Does Not Resist Displacement

Simple intermaxillary fixation of the remaining teeth of the lower jaw to the teeth of the upper jaw is inadequate when the fracture line extends downward and backward The pull of the elevator muscles of the jaw tends to displace the posterior fragment upwardly and medially (Figs. 145 146) A number of additional measures can be employed to control the posterior fragment.

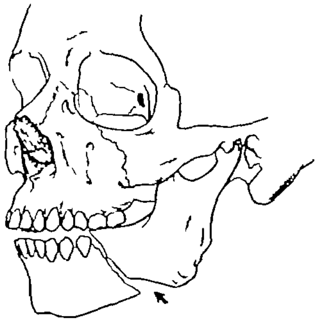

FIG. 145 Drawing illustrating a fracture of the mandible in which the angle and bevel of the fracture line favor displacement of the posterior edentulous fragment.

CONTROL OF THE POSTERIOR FRAGMENT BY INTERLOCKING THE FRAGMENTS. Fractures of the angle of the jaw may be immobilized in favorable cases by interlocking the fractured surfaces. Wires are fastened to the teeth of the upper and lower jaws by any of the methods previously described The posterior fragment is forced into its anatomical position by digital manipulation until the irregular surfaces of the fracture lines interdigitate and can be retained in that position *This procedure should be performed under local anesthesia and only* when the injury is recent and fragments are easily manipulated (Fig 147) The jaw is then immobilized by intermaxillary fixation

CONTROL OF THE POSTERIOR FRAGMENT BY

FIG 146 Roentgenogram showing the displacement of the posterior fragment inward and upward to a marked degree due to the pull of the elevator muscles of the jaw

Fig 147 Roentgenogram showing reduction and immobilization of fracture in the postmolar region by interlocking fractured surfaces immediately before wiring the jaws together

THE USE OF A BITE BLOCK. If the posterior fragment is edentulous (Fig 145) additional means of stabilization must be provided. As an emergency measure a small bite-block of dental compound or cork may be constructed to fill the edentulous space on the posterior fragment.

A more positive method especially adapted for comminuted fractures in the partially edentulous mandible, is shown in figure 148. The remaining teeth carry a cast metal splint, or an arch bar with a T extension over the injured area An acrylic bite-block, which controls the fragments on the edentulus side, also provides occlusal contact with the teeth of the maxilla in order to prevent upward displacement of the edentulous fragment (Fig 148D) A wire loop on the buccal aspect of the appliance acts as an occlusal guide buccal hooks are incorporated for the attachment of intermaxillary elastics. Direct osseous wiring, however is a more satisfactory method whenever feasible

CONTROL OF THE POSTERIOR FRAGMENT BY A FORKED WIRE EXTENSION A band and arch bar appliance is applied to selected lower teeth when the fracture extends behind the angle of the jaw The appliance terminates in a 14 gauge wire prong projecting backward across the fracture line and pressing downward against the bony ridge of the posterior fragment to prevent upward displacement. This appliance should be supplied with buccal wire loops and wire hooks to provide intermaxillary fixation Inflammatory reaction in the soft tissues is usually slight even with prolonged use of such an appliance (Figs. 149 150) Direct osseous wiring is also the more satisfactory method in most simple cases

BILATERAL FRACTURE IN THE RETROMOLAR REGION The forked wire extension is equally applicable in bilateral fracture of the retromolar region (Figs. 151 152) A capped or banded appliance, anchored to the teeth carries the forked extensions for immobilization of the posterior fragment this type of appliance should also be supplied with hooks for intermaxillary wiring

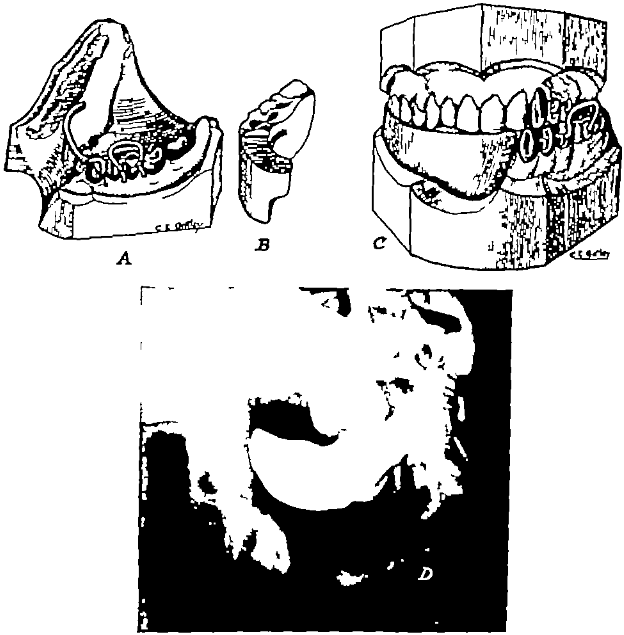

Fig 148 A. Drawing of a compound, comminuted fracture with a large edentulous fragment. A dental cap splint carrying a T-bar is cemented to the teeth.

B. A block of material designed to restore the contour and occlusal plane of the edentulous fragment fits over the T-bar

C. Bite-plate in contact with the upper teeth to control the comminuted fragments of lower jaw The splint is supplied with hooks and bite guide

D Roentgenogram showing an appliance similar to that pictured in A B and C fixing the fragments of the non-united fracture in position This appliance was used as an auxiliary splint during later transplantation of bone

Control of the Posterior Fragment by Direct Interosseous Wiring. Interosseous wiring of a fracture of the mandible may be accomplished by either the extra-oral or the intra-oral route

Interosseous wiring by the extra-oral route This method can be employed for the direct wiring of fractures of either the body or the angle of the jaw A small incision exposes the angle of the mandible Marked forward displacement of the angle increases the difficulty of locating the angle· the location of the skin incision may be established *in such cases by comparison with*

the unaffected side. The incision should be situated in or parallel to one of the skin folds of the neck (Fig 153) The fibers of the platysma muscle are separated after incising the skin. The incision when made at the proper level lies below the parotid gland thus protecting the mandibular branch of the facial nerve which lies within the parotid gland. The angle of the mandible is reached by dissecting the tissues deep to the platysma upward and forward The angle, after being grasped by a bone

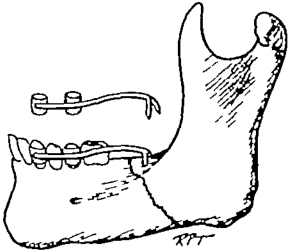

Fig 149 Drawing illustrating the manner in which a wire prong prevents displacement of the posterior fragment.

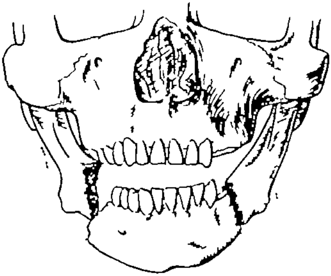

Fig 151 Drawing illustrating a bilateral fracture of the mandible with downward displacement of the body of the mandible due to the pull of the supra hyoid musculature. Note the upward and medial displacement of the right mandibular ramus by the elevator muscle pull.

forceps, is readily returned to its normal position in recent fractures. In the delayed reduction of such a fracture however some difficulty may be encountered in restoring the position of the angle because of the pull of the elevator muscles. In such cases an incision should be made in the periosteum along the posterior and lower borders of the

Fig 150 Roentgenogram showing the wire prong fixing the posterior fragment in its normal position

angle of the mandible and the masseter and internal pterygoid muscles elevated subperiosteally in order to release the muscular pull

After the posterior fragment is loosened and previous to the placing of interosseous wiring temporary intermaxillary fixation is established in order to immobilize the mandible in proper occlusal relationship One or two small holes are drilled in each fragment in the angular fragment and in the body of the mandible by means of a small burr activated by the electrically driven drill A figure of eight stainless steel wire is placed to maintain the position (Fig 153). Careful suture of the wound results in an inconspicuous scar

Interosseous wiring by the intra-oral route The technique of inter-osseous wiring through the intra-oral approach applicable to Class II fractures of the body of the mandible is described in the section devoted to Class III fractures (see Fig 176)

CONTROL OF THE POSTERIOR FRAGMENT BY EXTERNAL FIXATION The use of external fixation is described in more detail elsewhere in this chapter The external fixation method is particularly useful in cases of marked comminution or loss of bone in the

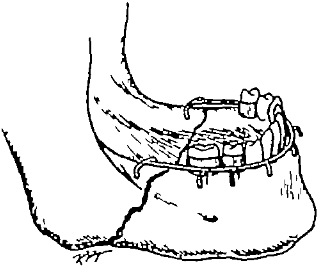

Fig 154 Drawing showing how wire prongs are employed for immobilization of the posterior edentulous fragments in bilateral fracture of the mandible Hooks are attached to the arch wires for intermaxillary fixation

molar or retromolar region of the mandible in order to maintain the posterior fragment in a backward position thus preventing it from being pulled forward by the elevator muscles of the jaw Interosseous wiring cannot be used in such cases. The types of appliances illustrated in Figs. 190 and 191 are of value In these cases the external fixation appliance is fixed to an intra-oral appliance fastened to the remaining teeth of the mandible

CONTROL OF THE POSTERIOR FRAGMENT BY EXTERNAL WIRE TRACTION (Lenormant and Darcissac 1927). This method is useful in cases of comminution or loss of bone anterior to the angle to control ramus displacement in early treatment. The angle of the mandible is exposed subperiosteally through a small skin incision A hole is drilled through the angle by means of a small round burr Stainless steel wire is passed through this hole and the wire ends are brought out through the skin posteriorly to the incision at the angle which is closed by suture The two wire ends are looped together over an elastic band which is then connected to a strong wire fixed to a head cap. Constant backward traction on the angle maintains the position Difficulty may be experienced with this method in controlling lateral or medial displacements of the posterior fragment

Both external fixation and wire traction are useful methods of fixation but should not be relied upon for reduction particularly in later treatment because the musculature is usually too powerful to permit reduction Open surgical reduction is preferable

IMMOBILIZATION WHEN THE UPPER JAW IS EDENTULOUS. In Class II fractures fixation *depends upon the presence of teeth in the upper jaw* Fixation is more difficult if the upper jaw is edentulous. The following method is utilized effectively in such cases. an upper bite-block is constructed with prongs extending from the corners of the mouth similar to the Kingsley splint and

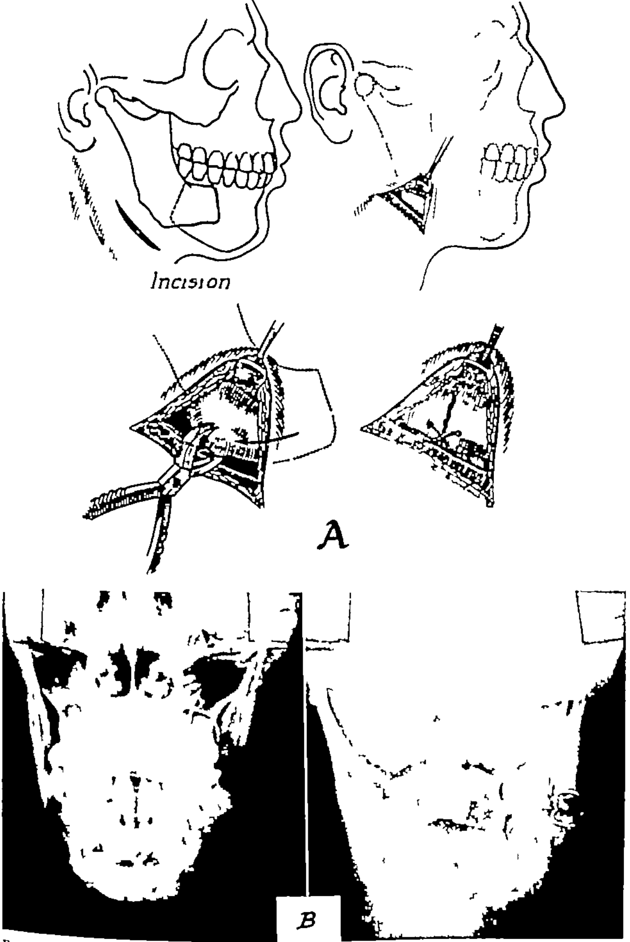

FIG. 153. A Diagrams illustrating the exposure of the fracture line through an incision below the angle of the jaw and open reduction of the fracture. The posterior fragment has been displaced forward and laterally to the anterior fragment.

B. Roentgenogram of a mandibular fracture showing marked displacement of the ramus on one side delayed treatment has resulted in inward and upward displacement of the ramus. The figure on the right side shows the interosseous wiring following external exposure of the fracture.

(J M Converse, J Oral Surg 3 112, 1945)

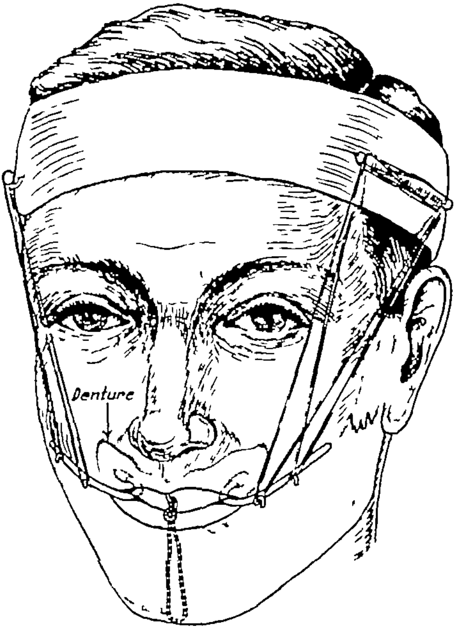

FIG 154 Drawing illustrating a method of immobilization of a bilateral mandibular fracture when the upper jaw is edentulous, showing a Kingsley splint attachment to the patient's upper denture The mandible is forced against the upper jaw by means of circumferential wiring passed around the mandibular symphysis. The circumferential wire is twisted labially forming a loop is passed around a hook, placed on the denture (see Fig 156) Elastics, extending upward from the external bars of the Kingsley splint fasten the upper denture to a headgear (see Figs 153 and 157) Fixation of the mandible to the denture and of the denture to the cranium is thus obtained

firmly retained attachments to an external head cap (Figs 151 to 157) The lower jaw is then forced against the bite-block and held in position either by elastics or wires connected to small hooks along the buccal side of the bite-block (Fig 155) The effectiveness of this method depends upon the condition of the lower teeth When lower incisors are absent or if they are not strong enough to sustain upward pressure of the mandible a circumferential stainless steel wire can be passed around the symphysis, the ends of the wire protruding through the gingival tissue (Figs. 154 156) The wires

are twisted together and a loop is formed on the labial aspect in the region of the incisor teeth. Fixation of the lower jaw to the bite-block can then be accomplished more effectively by passing wires through the loop to buccal hooks on the bite-block. Other methods of direct wire fixation of the bite-block or denture to the maxilla are described in Chapter 7

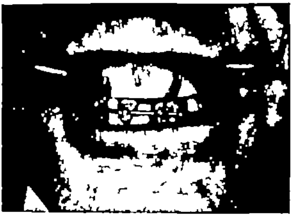

FIG. 155. Photograph showing a Kingsley splint with elastics connected to small hooks along the buccal surface of a lower arch wire forcing the lower jaw against an upper bite-plate in bilateral fracture of the mandible.

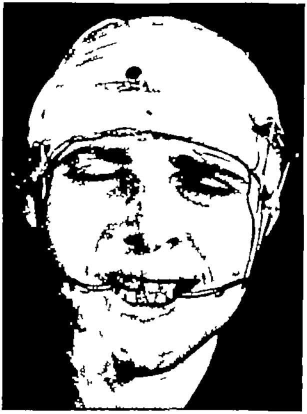

FIG 157 Photograph showing a dental splint on the mandibular teeth fastened to an upper denture by means of elastics in a bilateral fracture of the mandible.

FIG 156. Roentgenogram showing mandibular circumferential wiring fastened to a splint on the edentulous maxilla (see also Fig 154)

Control of Comminuted Fragments. In the average type of comminuted fracture the bone is usually protected and supported by the surrounding mucoperiosteum and soft tissues and direct interosseous wiring usually maintains fixation of the multiple fragments.

In compound fractures, such as those incurred in gunshot wounds, the comminuted fragments may be deprived of soft tissue protection and the unrestricted pull of the muscles causes extreme displacement of fragments. Figure 158*A* illustrates this type of fracture: the upper surfaces of the fragments are usually exposed through the wound. Immobilization can be accomplished by the use of an intra-oral appliance and wire suspension (Fig. 158*B*). When serviceable teeth are present on the larger mandibular fragments as well as in the upper jaw, the lower teeth are banded or capped and are used for anchorage; a forked arch wire extending posteriorly from the bands, is attached to the edentulous fragment by inserting the prongs of the wire into a hole drilled through the fragment. The pronged arch wire thus controls the main fragment. The displaced fragments between the two main segments of bone are suspended to the arch bar. Supplementary support is provided by an upper dental appliance supplied with hooks for intermaxillary fixation.

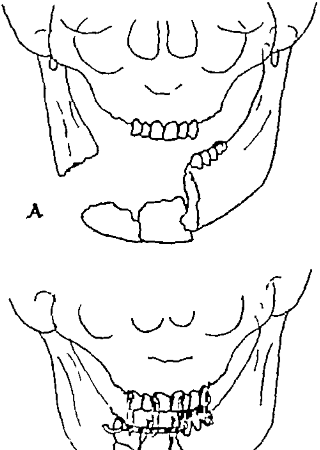

Fig. 158. A, Diagrammatic drawing illustrating *comminuted fragments in mandibular fracture subjected to unrestricted muscle pull.*

B, Drawing illustrating control of extensively displaced fragments by splinting in combination with direct interosseous wiring.

(V. H. Kazanjian, Am. J. Orthodontics & Oral Surg. 28:551, 1942.)

Immobilization is complicated in severely comminuted fractures of the mandible when the upper jaw is edentulous. We have employed a banded intra-oral appliance over the remaining lower teeth in such cases. An arch bar extends over the comminuted fragments which are suspended by wires to the arch. The ramus on the opposite side is controlled by interosseous wiring (*Fig. 159*).

An upper bite-block should be employed to occlude with the lower teeth on one side and the alveolar process on the opposite side (Fig. 159). The mandible can be further immobilized by a firmly applied figure-of-eight bandage; a bandage, however, may not be practical, for almost all such fractures are associated with soft tissue wounds of the lower part of the face.

Fractures of the Neck of the Condyle

The temporomandibular joint is usually protected from direct injury by the zygomatic arch. Because of the structural complexity *of the temporomandibular joint*, fractures in this area are often best treated by simple methods. It is interesting to note that the temporomandibular joint may be subjected to prolonged periods of immobilization without being ankylosed.

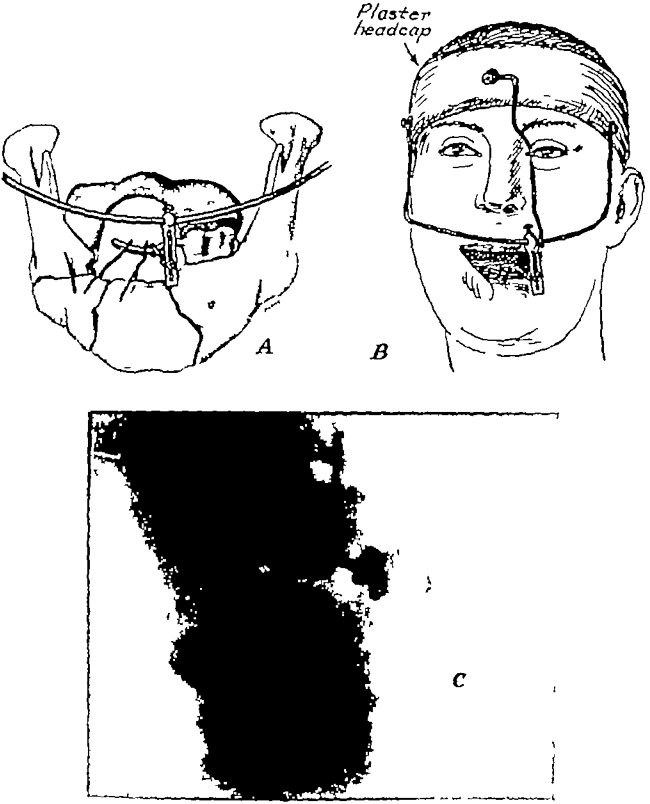

FIG. 159 A. Drawing showing a method of immobilization in extensive displacement of comminuted fragments of the mandible associated with an edentulous upper jaw. One fragment is attached to the ramus by interosseous wiring. A dental splint is cemented to the remaining mandibular teeth. An upper dental bite plate gives occlusal contact.

B. An external appliance immobilizes the entire lower jaw.

C. Roentgenogram showing condition illustrated in A.

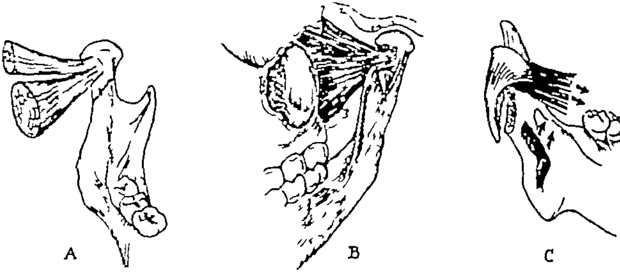

Fig 160 Mechanism of displacement in fracture of the neck of the condyle

A. Illustrates insertion of external pterygoid muscle to the condyle (medial view)

B. The origin of the external pterygoid muscle from the infratemporal surface of the greater wing of the sphenoid bone and from the outer surface of the lateral pterygoid plate accounts for the anteromedial displacement of the condyle after fracture.

C. Shows typical anteromedial displacement after fracture of the condylar neck, resulting from the pull of the external pterygoid muscle (posterior view)

Surgical Pathology

The condyloid process of the mandibular ramus consists of a head and a narrowed supporting neck (Fig 160) *A depression on* the anteromedial aspect of the condylar neck is the site of insertion for the lower fibers of the external pterygoid muscle this muscle tends to displace the condylar head anteriorly and medially when the neck of the condyle is fractured below the insertion of the muscle (Fig 160C) The condylar head is wider transversely than anteroposteriorly It is covered with cartilage the lower margins serving as areas of attachment for the articular capsule by which the head of the condyle is suspended from the mandibular fossa and articular tubercle of the squamous temporal bone

An impact on the chin may result in unilateral or bilateral condylar fracture since the neck of the condyle is the weakest part of the mandible

Condylar fractures have been classified as intra and extracapsular the differentiation depending upon whether the fracture line extends above or below the line of insertion of the articular capsule Such an anatomic classification has no value in surgical treatment the level of the fracture line, above or below the point of insertion of the external pterygoid muscle however is of surgical importance for the condylar fragment is subjected to displacement by the action of the muscle when the fracture line extends below its insertion. The anterior *medial and slightly upward pull of the* external pterygoid muscle is an important factor in the typical displacement of the condylar fragment in that direction (Fig 160C) The joint capsule is thin and not well supported on the medial aspect Rupture at this site with medial dislocation of the condylar head is a relatively frequent occurrence The powerful upward pull of the masseter internal pterygoid and temporalis muscles on the ascending ramus frequently produces an overriding of the fragments.

This type of displacement results in a backward and upward displacement of the mandible the ramus is elevated resulting in an open bite condition (Fig 161) An open bite condition also results from bilateral fractures of a similar type (Fig 162)

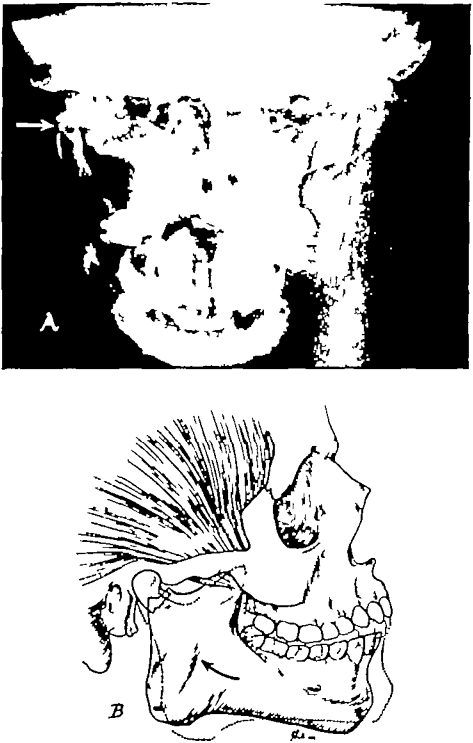

Fig 161 A. Roentgenogram showing head of the right mandibular condyle displaced medially at right angle to the ramus.

B. A drawing illustrating displacement in unilateral fracture of the neck of the mandibular condyle. The only contact between the upper and lower teeth is in the third molar region, and the lower jaw is deviated toward the injured side. The arrow indicates the direction of displacement

The condyle is usually moderately displaced, but in some cases it may be luxated out of the mandibular fossa.

Condyle fractures are classified as displacement fractures, the head remaining within the limits of the temporomandibular joint, and dislocation fractures, in which the fragment is expelled from the joint fossa The condylar fragment may be displaced in an anterior, medial posterior or lateral direction in each of these fracture types.

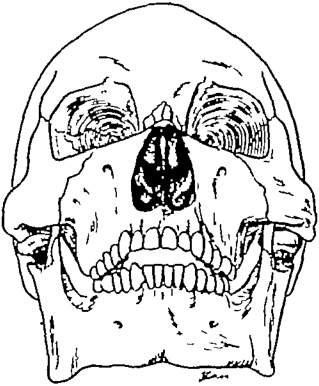

FIG 162 Drawing illustrating displacement in bilateral fracture of the neck of the mandibular condyle with backward displacement of the mandible contact of upper and lower teeth occurs only in the third molar region

The degree of injury varies from a simple linear fracture without displacement or with only slight angulation at the fracture site to severly comminuted fractures. Associated injuries to the joint capsule ligaments and meniscus may also occur

Fracture of the tympanic plate which forms a portion of the anterior wall of the external auditory canal may result in obstruction of the external auditory canal due to subperiosteal hematoma

Examination and Diagnosis

CLINICAL EXAMINATION Displacement is usually lateral and backward in unilateral fracture the most common of condylar fractures The chin is deviated toward the injured side and asymmetry is noted in the lower part of the face Normal occlusion of the teeth is disturbed contact between upper and lower teeth often occurring only in the posterior region of the affected side (Fig 161B) Because of the shortening of the ramus on the fractured side a tilting of the body of the mandible results in an open bite on the opposite side Further examination reveals swelling and tenderness over the temporomandibular joint and partial trismus. Figure 161 A shows a medial displacement of the condyle out of the glenoid fossa Bilateral subcondylar fracture results in symmetrical backward displacement of the entire mandible also manifested in an open-bite in the incisor and bicuspid regions (Fig 162)

Digital palpation in the external auditory canal reveals a point of tenderness upon pressure on the anterior wall of the canal Fracture dislocation of the condyle is suggested when the mandible is moved through its full range of motion and the palpating finger fails to elicit condylar movement

In unilateral fracture of the condyle the mandible may deviate toward the affected side when the patient is requested to open the mouth this deviation is produced by the contraction of the external pterygoid muscle on the unaffected side unopposed by the non functioning external pterygoid muscle on the fractured side The fact that the patient cannot move the mandible toward the unaffected side is evidence that the external pterygoid muscle is not functioning on the affected side This is an important diagnostic sign in fracture of the neck of the condyle below the insertion of the external pterygoid muscle Side to side movements, however are still possible in cases where the neck of the condyle is fractured at a higher level because of the *preservation of internal pterygoid function* and also because the insertions of the external pterygoid muscle may extend below the line of fracture muscular contraction thus acts upon the ramus, permitting the mandible to move toward the opposite side

ROENTGENOGRAPHIC EXAMINATION Roentgenographic examination (see Chapter 15) may reveal an overriding of the fragments and forward or backward displacement of the neck of the condyle (Fig 163) the con

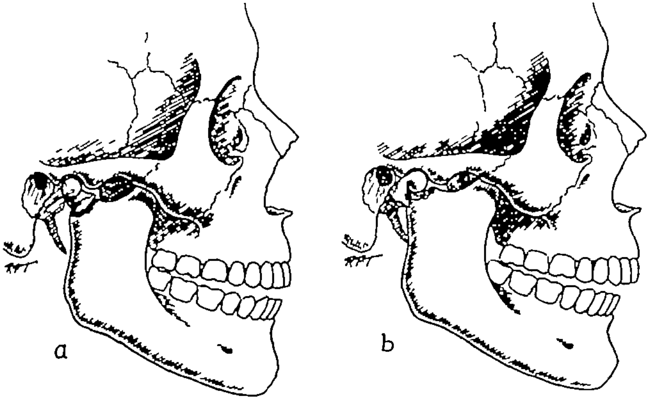

FIG. 163 Diagrams of fractures of the neck of the condyle. The condylar head may remain in the glenoid fossa with the neck of the condyle assuming a slightly forward (A) or backward position (B)

dylar head remains in the mandibular fossa In addition to the overriding of fragments the head of the condyle may be luxated backward (Fig 164) or medially (Fig 161*A*) from the fossa toward the base of the skull We have observed cases of forward and inward displacement of the head of the condyle completely out of the glenoid fossa but with the two fractured surfaces still in apposition the affected side of the mandible is displaced forward in fractures of this type. Figure 164 shows an unusual forward displacement of the mandible due to backward displacement of a dislocated fractured condyle

The treatment of subcondylar fractures varies according to whether one is dealing with a simple or a compound comminuted fracture.

Treatment

Intermaxillary fixation alone achieves adequate reduction in the majority of condylar fractures. When the teeth are placed in occlusion by intermaxillary traction and fixation the body of the mandible is tilted this draws the angle down on the affected side and the overriding of the ramus and condyle is corrected. Although this type of conservative treatment does not correct the position of the medially displaced condylar head the maintenance of bony contact between the condylar fragment and the ramus results in consolidation. It is not essential to achieve perfect anatomical relationships in this type of fracture, for good function is restored by drawing the lower jaw forward until the teeth occlude. The occlusion must be maintained by intermaxillary fixation until union is established (Fig 165) Four to five weeks of immobilization are usually sufficient (Fig 166)

Manipulation of the fractured condylar head with a sharp-pointed instrument through the oral cavity fails to give the desired results. Although some surgeons advocate open reduction in order to re-align the fragment by means of interosseous wire fixation a greater number feel that conservative treatment affords satisfactory results. To clarify the principles of condylar fracture management, the members of the

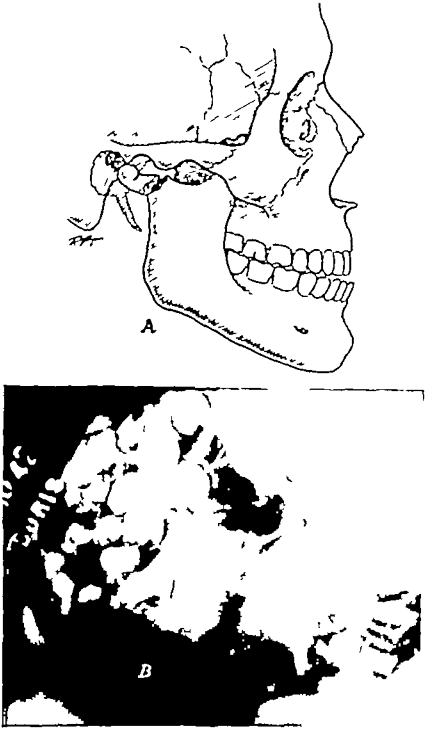

Fig. 164. Diagram (A) and roentgenogram (B) showing unusual forward displacement of the lower jaw resulting from a fracture of the neck of the condyle. This type of case necessitates open reduction.

Chalmers J. Lyons Club (1917) organized a comprehensive study of 120 cases of condylar fracture. A summary of the compiled statistics appears in Tables 4 and 5.

Closed reduction and intermaxillary fixation are favored in the treatment of condylar fractures. X-ray evidence of the re-alignment of the fragments in correct anatomic position is not the aim of treatment. The results of the survey show that consolidated condylar fractures do well and function is satisfactory without accurate re-alignment of fragments. Manipulation under general anesthesia is helpful when repositioning the fragments before immobilization. Anterior intermaxillary elastic traction may be used

to correct an open bite Posterior bite plates, blocks and appliances, used in the posterior region to provide a fulcrum effect, correct overriding of the fragments. Intermaxillary fixation should be applied as soon as possible after manipulation of the mandible has replaced the dentition in proper occlusion Since fractures of the condyle are

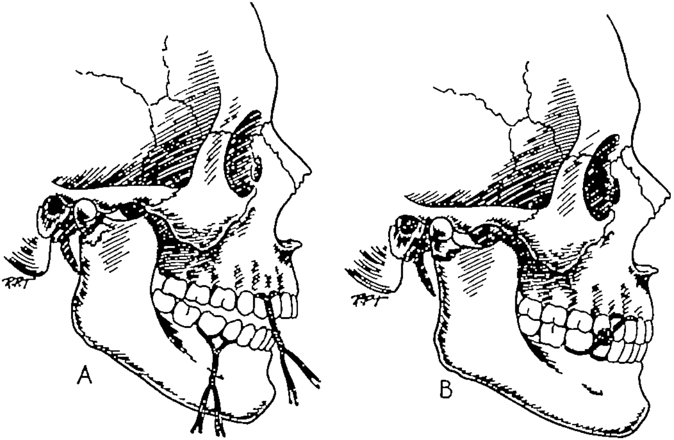

FIG 165 Diagram showing an example of backward displacement of the mandible reduced by wiring the lower molar and second bicuspid teeth to the upper bicuspid and cuspid to effect forward pull of the lower jaw Direction of the wires should be carefully considered in order to effect a pull in the direction toward normal occlusion

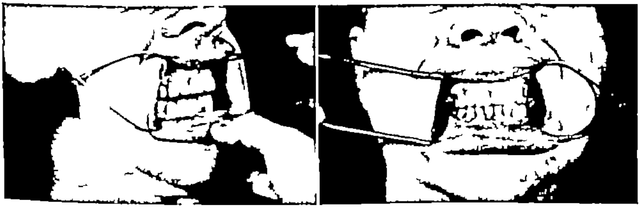

FIG. 166

(*Left*) Photograph showing bilateral backward displacement of the lower jaw and open bite due to bilateral fracture of the neck of the mandibular condyle. There was also a fracture in the median line between the incisor teeth.

(*Right*) Photograph after immobilization by wiring The fracture in the median line was immobilized by horizontal wiring of the teeth on each side. Intermaxillary wiring was employed to fix the teeth of both jaws in occlusal relationship

TABLE 4

Analysis of 120 Cases Followed up after Condylar Fractures General Statistics

Total no. of cases	120
Male	70
Female	50
Average age of patient	28 yrs.
Youngest	4 yrs.
Oldest	65 yrs.
Site of fracture	
Condylar neck	
Unilateral right	29
Unilateral left	52
Bilateral	36
Intracapsular	3
Position of condylar fragment	
No displacement	30
Displacement	
Anteromedial	39
Anterolateral	12
Posterior	5
Dislocation	
Anteromedial	14
Posterior	6
Lateral	1
No available x ray evidence for location	6
Associated mandibular fractures	
None	39
Single	63
Multiple	18

often associated with other fractures, intermaxillary fixation provides a combined form of treatment.

Open reduction of condylar fractures is a hazardous procedure introducing additional trauma and inviting infection and cicatricial complications. Surgical exposure of the area is difficult. Damage to the internal maxillary artery and branches of the facial nerve may also occur

Altered function is a significant complication in condylar fracture Such a disturbance may vary from an asymptomatic limitation of side to side excursions of the mandible to possible ankylosis of the joint. Major complications were rare occurrences in the series of 120 cases which were treated conservatively Ankylosis is rarely a complication of condylar fractures. One case of ankylosis resulting from a condylar fracture was found in the review Since the condyle is a site of endochondral bone formation for the first 16 to 21 years, it has been suggested that condyle fractures in children may disturb the development of the ascending ramus. The children in this series exhibited no abnormal mandibular growth discomfort or dysfunction at follow up examinations. The results of this survey support the concept that conservative management yields satisfactory results with minimum difficulties.

A case which was brought to our attention (Gregory 1957) is that of a girl aged eight years, who sustained a subcondylar fracture of the mandible on the right side when she fell while riding on her bicycle Roentgenographic examination revealed a marked medial displacement of the right condyle (Fig 168*A*) the teeth were wired in occlusion by means of intermaxillary wires (Fig 168*B*). Consolidation was completed with the head of the condyle at right angles to the ramus (Fig 168*C*). The patient had no trouble in masticating food but

TABLE 5

Analysis of 120 Cases Followed up After Condylar Fractures Treatment of Cases Followed up

Treatment	
Intermaxillary fixation, closed reduction	108
General anesthesia during reduction	10
Average period of intermaxillary fixation	5 wks
Soft diet and observation only	10
Open reduction with direct wire fixation	0
Open reduction to position dislocated head	2
Survey of cases followed up	
Clinical examination	60
Correspondence	60
Average interval between treatment and follow up survey	5 yrs
Shortest interval between treatment and follow up survey	8 mos
Longest interval between treatment and follow up survey	19 yrs
Complications	
Ankylosis	0
Deformity	0
Functional disturbance of any type	

there was a deviation of the mandible to the affected side when the mouth was opened wide. She was instructed to stand before a mirror and exercise her jaw daily Radiographs taken three years later (Fig 168*D*) show nearly normal position of the condyle, satisfactory growth position and function of the mandible

Open reduction of the fracture is indicated in some cases for example when the condyle has been displaced out of the mandibular fossa (Fig 164) Removal of the condylar head may sometimes be required as in comminuted fractures followed by infection or fibrosis.

Adequate reduction is usually attained by wiring the fragments in proper alignment. We usually employ a pre auricular incision to expose the temporomandibular joint area The zygomatic arch is exposed and the soft tissues of the area are retracted forward. Adequate exposure can be obtained below the zygomatic arch. The lower fragment is exposed subperiosteally It is possible to manipulate the condylar fragment and to expose the condylar neck portion of the fragment by penetrating into the joint with an elevator Small holes are then drilled through each fragment and they are joined by direct interosseous wiring The articular meniscus should be removed when severely damaged. The soft tissue wound is then closed by interrupted sutures and a pressure dressing is applied to the area

Adequate function has been restored in all of our own series of cases when the head of the condyle has been forced out of its position a lessening of the side to side motions of the jaw may result but limitation of motion is slight and does not materially affect mastication Figure 167 shows a case of bi

FIG. 167 Roentgenogram showing fracture of right and left mandibular condyles with dislocation of both condylar heads out of the glenoid fossae. Treatment consisted of simple intermaxillary wiring for a period of five weeks a good functional result was obtained

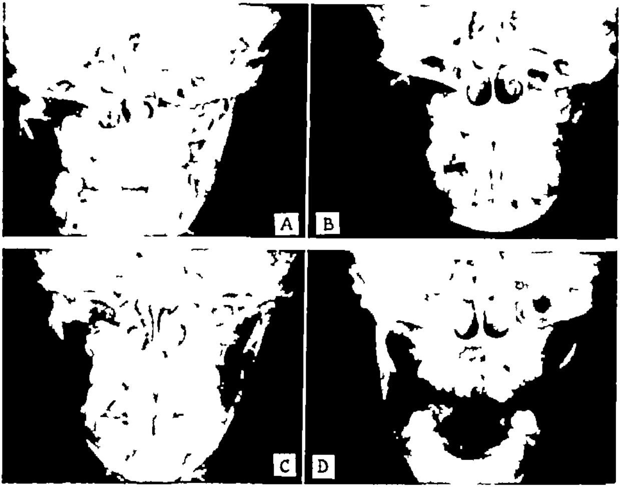

FIG. 168. Healing of a subcondylar fracture in a child (courtesy of Dr. T. G. Gregory).
A. Subcondylar fracture on right side with angulation medially.
B. Intermaxillary wire fixation has been assured.
C. Appearance of fracture after consolidation.
D. Three years later the right condylar process has resumed an adequate vertical position.

condylar fracture with dislocation of both condylar heads out of the mandibular fossae, a satisfactory functional result was obtained in this case by simple intermaxillary fixation. Figure 168 shows satisfactory healing of a subcondylar fracture in a child.

COMPOUND COMMINUTED SUBCONDYLAR FRACTURES. This type of fracture results from severe injuries; soft tissue injury is associated with the fracture and the joint capsule is penetrated. Extensive comminution and bone loss may occur if the fracture is due to a gunshot wound.

Treatment of these fractures includes care of the external wound and immobilization of the mandible. Infection involving the temporomandibular joint eventually leads to partial or complete ankylosis. If infection cannot be kept under control with conservative treatment, it is advisable to remove the head of the condyle through the open wound as soon as the sepsis is controlled and then to immobilize the remaining part of the jaw in its normal position. Such an operation shortens the healing period and minimizes the formation of scar tissue, thus preventing ensuing ankylosis. The effect of such a procedure is similar to that of an operation for the relief of ankylosis in which a section of the bone is removed from the temporomandibular region. The jaw is capable of adequate function even though retaining only a hinge-like motion in such cases.

Fractures of the Coronoid Process

Fracture of the coronoid process of the mandible is a rare occurrence. Such fractures show little displacement and require only conservative treatment because the fragment is splinted by the insertions of the temporalis muscle Unless mandibular function is impeded no special treatment is required.

Acute Condylar Dislocation

Dislocation of the mandibular condyle from the glenoid cavity may occur either unilaterally or bilaterally when the mouth is opened widely or when the joint is subjected to sudden violence the condyle being pushed over the articular tubercle through the articular ligaments into the zygomatic fossa The mandible then becomes fixed in this position as a result of the contraction of the elevator muscles of the jaw

To reduce the dislocation the operator stands behind the patient the fingers of both hands are placed beneath the jaw and the thumbs are placed into the mouth on the occlusal surfaces of the molars The patient is requested to relax and the jaw is moved up and down until complete relaxation is attained. At this time pressure is exerted in a downward direction and the dislocated condyle usually snaps into the mandibular fossa. When trismus resists mandibular motion the dislocation is reduced under general anesthesia

Treatment of Class III Fractures

Fractures in Which the Fragments are Edentulous

The incidence of mandibular fracture in edentulous patients is relatively low The teeth are occasionally avulsed in severe injuries, transforming a Class I or II fracture into a Class III fracture in an edentulous jaw Such fractures usually present similar characteristics they often occur in the older age group the mandibular bone may be atrophied and frail the fragments often override each other (Fig 169) the bone may be fractured bilaterally (Fig 170) They are usually simple fractures since the mucosa usually remains intact, and the healing process is rapid and seldom complicated by infection even when the patient is of advanced age fracture occurs most frequently in the bicuspid and molar regions and less frequently at the mandibular angle.

Methods of immobilization described for Class I and II mandibular fractures are not applicable for edentulous jaws nor can these methods be used when teeth are loose. Fixation must therefore be based on an entirely different plan One of the following methods may be employed (1) Fixation by means of intra-oral appliances or the patient s artificial dentures (2) circumferential wiring (3) direct fixation by interosseous wiring and (4) external fixation.

FIXATION WITH INTRA-ORAL APPLIANCES. Immobilization of the fracture with the aid of intra-oral appliances or dentures is indicated in simple cases when the fragments do not override each other Although displacement is slight, soft tissue reaction occurs, and the mucosa surrounding the fracture is swollen and tender

Undamaged artificial dentures can be utilized if the base of the lower denture is re adapted to the modified contour of the alveolar ridge. Even slight displacement and swelling prevents the contour of the mandible from conforming to the denture. The border of the lower denture is therefore trimmed and relined with dental compound (Fig 171) Failure to take this precaution results in ulceration of the mucosa and causes unnecessary suffering If the patient s dentures are not available impressions are made of the upper and lower jaws and two independent base plates and bite blocks are constructed

Any discrepancy in adaptation may be adjusted by trimming the occlusal surfaces of the dentures or by the addition of dental

FIG. 169. Roentgenogram showing overriding of fragments in fracture of the edentulous mandible in a patient 72 years of age.

FIG. 170. Roentgenogram of bilateral fracture of the edentulous mandible.

compound (Fig 172) The purpose of the denture is to support the fragments. A simple external headgear with elastic band traction assists in supporting the jaw after the dentures are inserted

We do not advocate the use of one-piece intermaxillary splints as originally devised by Gunning (1866–1867) during the American Civil War because the laboratory techniques are complicated and accuracy is rarely attained. Two-piece base plates of acrylic are simpler to construct and are easily adjusted.

CIRCUMFERENTIAL WIRING. This method aims to immobilize fragments by a stainless steel wire passed around the bone. According to Ivy (1922) circumferential wiring of the mandible was originally employed by Black. As first advocated the method aims at controlling fragments by means of a bite-block fitted over the alveolar ridges wires are passed around the bone over the bite-block and tightly twisted. This type of circumferential wiring is useful in fractures with an oblique fracture line to immobilize overriding fragments after reduction.

Circumferential wiring should be used without an acrylic bite-block (Fig 173) for the bite-block cannot be controlled thereby jeopardizing fixation as well as causing pressure necrosis even though the wire cuts through the mucosa the defect is small and heals spontaneously Circumferential wiring can also be used as described in the intra-oral wire technique (Fig 176) Direct interosseous wiring is usually a more advantageous method of treatment.

Figure 174 illustrates a case of comminuted fracture of the body of the mandible on the right side and bilateral fracture of the neck of the condyle associated with a pyramidal fracture of the maxilla. The patient was injured in an automobile crash and was admitted to a hospital where an emergency tracheotomy was performed. When the patient was first examined the maxilla was loose and all the maxillary teeth were loosened except for five anterior teeth. The mandible was markedly retracted with open bite between the incisor teeth. The few remaining teeth in the mandible were very loose. Fixation of the mandibular fragments was obtained under general anesthesia by a circumferential wire passed around the fragments of the right body of the mandible, and two circumferential wires around the symphysis (Fig 174) One wire was looped around the symphysis, the ends of the wire were twisted and a

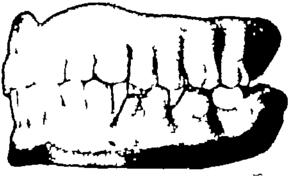

Fig 171 Photograph showing the use of a patient's upper and lower dentures to immobilize edentulous mandibular fractures when the displacement of the fragments is slight The lower denture is relined with dental compound.

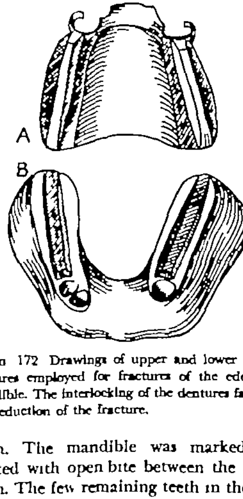

Fig 172 Drawings of upper and lower occlusal dentures employed for fractures of the edentulous mandible. The interlocking of the dentures facilitates the reduction of the fracture.

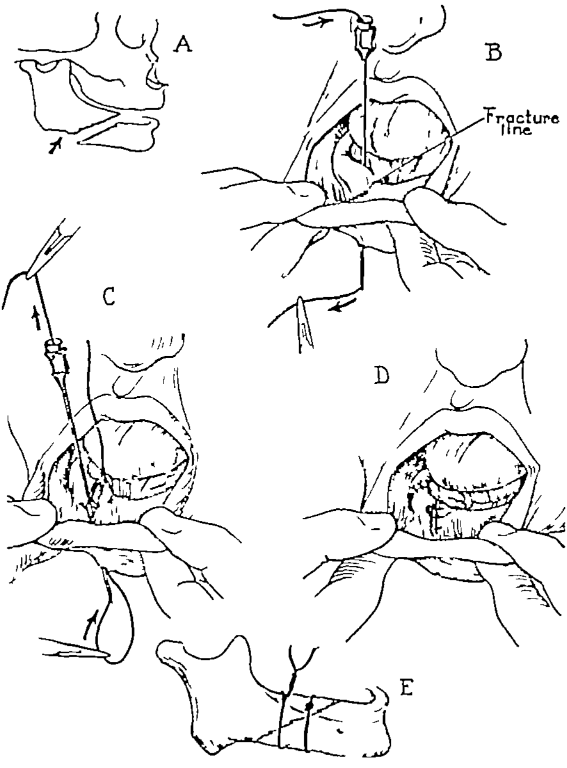

Fig 173 The technique of circumferential wiring

A Oblique fracture of an edentulous mandible

B A heavy gauge needle for example a needle used for lumbar puncture is placed on the lingual aspect of the mandible and transpierces the floor of the mouth and the soft tissues to the inframandibular area A stainless steel wire is threaded through the needle

C After an incision through the mucoperiosteum, the needle is placed on the labial aspect of the mandible and is brought out through the skin through the same opening The stainless steel wire is threaded through the needle in the opposite direction

D The wire is twisted over the alveolar crest the mucosa is sutured

E Illustrating fixation of fragments by two circumferential wires

FIG. 174 Roentgenogram showing maxillary fracture, comminuted fracture of the body of the mandible on the right side and bilateral fracture of the neck of the condyle

button was formed and protruded through the skin under the mental symphysis An other circumferential wire around the symphysis was looped around the arch bar of a banded intra-oral appliance applied to the teeth of the anterior portion of the maxilla. After the patient recovered from anesthesia a cranial fixation appliance (Fig 175) was employed to provide forward and upward traction of the mandible against the maxilla and of the maxilla to the skeletal framework of the face The upward traction assisted in the consolidation of the maxillary fracture and forward traction provided reduction of the fragments of the bilateral subcondylar fracture

DIRECT INTEROSSEOUS WIRING. Direct interosseous wiring is indicated in fractures of the edentulous mandible with marked over riding of fragments, and in compound or comminuted fractures. Either the extra-oral route through an incision below the border of the mandible or the intra-oral route may be employed

Extra-oral route The extra-oral route has been described previously in this chapter (see Fig 153)

Intra-oral route with pull-out wire This technique has long been used by the authors with excellent results. A simple intra oral method for the fixation of fractures of the edentulous mandible consists of exposing the fracture line through an incision over the crest of the alveolar ridge a horseshoe incision in the vestibule permits raising a mucoperiosteal flap and obtaining a wider exposure of the fracture site a necessary requirement if there is marked over riding of the fragments.

The mucoperiosteum over the broken ends of the bone is then reflected back sufficiently to permit drilling a hole near the end of each fragment. A stainless steel wire is passed through the holes the fragments are manipulated into position and the wires are twisted together to retain the ends in apposition (Fig 176) The twisted ends of the wires are of sufficient length to protrude through the mucosa into the mouth the edges of the mucoperiosteal incision are sutured Little inflammatory reaction oc

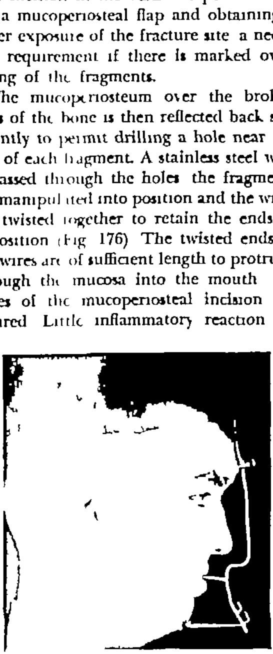

FIG 175 Photograph of patient with the cranially fixed appliance providing upward and forward traction at the mental symphysis.

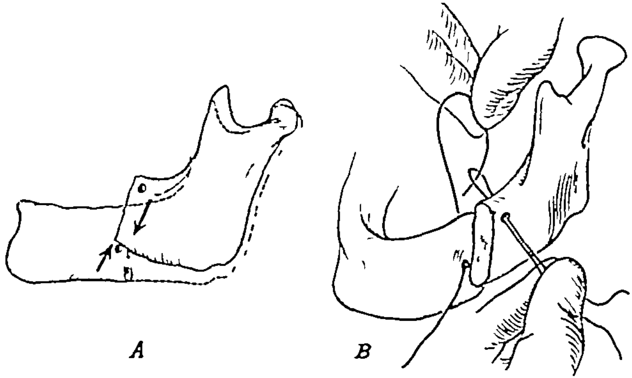

FIG. 177. A. Drawing illustrating the location of holes drilled through each of the fragments. The arrows indicate the direction of pull of the interosseous wiring employed in reduction of the fracture. The hole is drilled near the alveolar crest of the fragment which is displaced upward, while the hole through the anterior fragment is drilled at the lower level. When the fragments are approximated a greater pull is thus exerted on the posterior fragment.

B. Illustrating the technique employed in passing the interosseous wire through the prepared holes. A loop is passed through the buccal side to receive the free end of the wire and to retract it.

curs, since the operation causes a minimum amount of trauma at the site of fracture. The advantages of this procedure over extra-oral wiring and extra-oral skeletal fixation may be summarized as follows:

1. Exposure of the fracture line by reflecting back the muco-periosteum is a relatively simple procedure resulting in less operative trauma than exposure by means of the external route.

2. Reduction is accomplished under direct vision.

3. *Local anesthesia may be employed in favorable cases.*

4. No additional manipulation is necessary after operation. An interdental appliance accurately fitted to the upper and lower alveolar ridges may provide additional support but is not an essential requirement.

5. The technique requires only simple equipment such as wires and drills of a suitable gauge which are usually available.

The mucoperiosteum may be reflected quite freely on the buccal side when exposing the fractured ends but care should be exercised on the lingual side of the mandible, as excessive trauma to the mylohyoid muscle and loose tissues of the floor of the mouth may result in considerable edema. The overriding edges are wedged apart with a periosteal elevator after exposure of the fractured area. A hole through the posterior fragment, which is usually displaced upward, is drilled near the crest of the alveolar ridge, and the hole through the anterior fragment is drilled at a lower level; the upward pull of the posterior fragment can thus be controlled when the fragments are approximated (Fig. 177). A bilateral fracture of the edentulous mandible is shown in Figure 178. Either a hand drill or a den

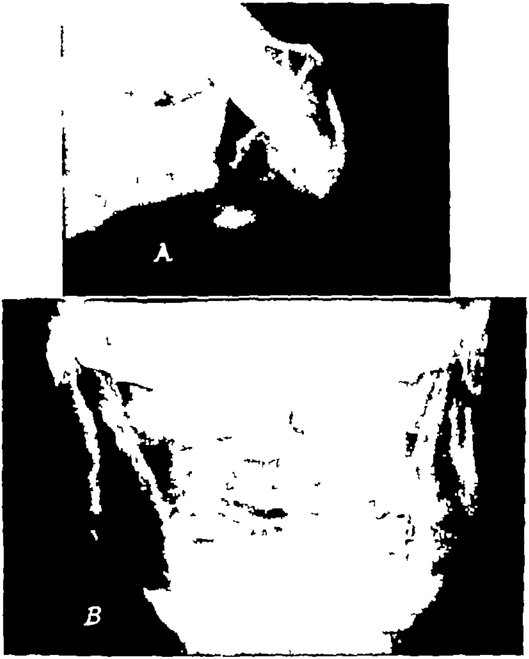

Fig 177 A. Roentgenogram showing overriding fracture through the body of an edentulous mandible in a man aged 82 years.
B The fragments reduced by interosseous wiring

Fig 178 A. Roentgenogram showing bilateral fracture of lower jaw reduced by interosseous wiring
B. Roentgenogram of completed case shown in A consolidation of the fracture is achieved

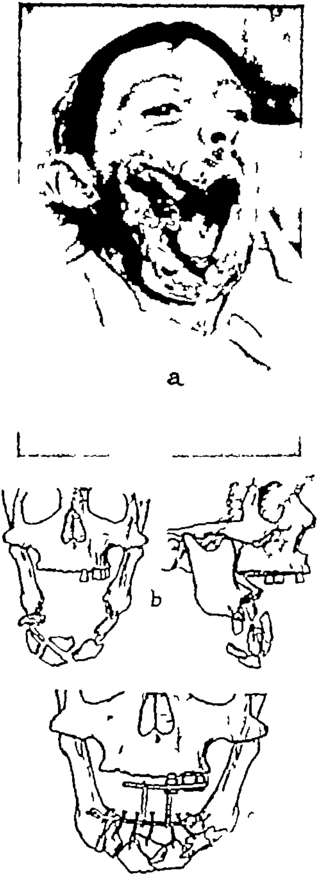

Fig. 1 A. Extensive comminution of the mandible ... fragments of bone markedly displaced ...

tal engine may be used; the drill hole should not exceed 1.5 mm in diameter. Threading a stainless steel wire through the bone from the buccal to the lingual side is a relatively simple procedure; to return the wire back from the lingual to the buccal side, however, an additional loop of wire is introduced from the buccal side to receive the free end of the wire and to draw it back (Fig. 176B).

After the wires are passed through the holes, the ends are twisted together until good approximation is obtained. The twisted ends should be cut short if it seems preferable to leave the wires in place permanently. The wires should be long enough, however, in order that they may be easily withdrawn after the fracture has consolidated (Figs. 177, 178).

There seems to be widespread misunderstanding regarding the surgical approach in the wiring of bone fragments. An objection to the oral route has been that it invites infection; we have not experienced this complication. Such an operation is feasible even in a patient of advanced age (Fig. 177).

Comminuted and Compound Fractures of the Edentulous Mandible

Comminuted and compound fractures of the edentulous mandible associated with soft tissue lacerations are rare. The authors, however, have treated wounded soldiers who had suffered such extensive comminution of the lower jaw that all the teeth were either avulsed at the time of injury or removal of the teeth was a necessity to avoid infection. In such cases the body of the mandible usually consists of several fragments of bone which are displaced downward and backward t ... ase of the tongue (Fig ... s the greater part of ... sing and the lower

mand

ible

border of the ramus on both sides was exposed through the oral wound. Extensive soft tissue damage of lip, chin or cheek tissue are concomitant factors.

To immobilize a comminuted edentulous fracture with extensive displacement of the fragments, good results have been obtained by suspending the anterior pieces of bone to a bar anchored to the posterior fragments. A hole is drilled bucco-lingually through the alveolar bone of each posterior fragment. A heavy arch bar, to which a prong is soldered at each end, is then anchored to the segments. The curve of the arch bar corresponds generally to the normal curvature of the mandible. Small holes are drilled through the exposed ends of the displaced anterior fragments and fine stainless steel fracture wires are passed through these holes. The fragments are drawn upward and forward until they are in good alignment; they are then suspended by attaching the individual wires to the arch bar (Fig. 179C).

Loss of part of the lip and chin is usually associated with loss of bone in the anterior section of the edentulous jaw. Even though a large section of the body of the mandible may be missing, it is important that the remaining posterior segments are retained in good serviceable position for future restorative purposes; external skeletal fixation and intra-oral appliances are recommended to achieve this purpose.

External Fixation in Mandibular Fractures

External fixation by metallic pins placed through the skin and soft tissues for the fixation of the fragments of fractured long bones was extensively used by Lambotte (1913) and later by Anderson (1936). Berchet and Ginestet (1934) described a single pin appliance for fixation of mandibular fractures. Converse and Waknitz (1942) employed the Roger Anderson appliance in fractures of the angle of the mandible. Clouston and Walker (1943), MacGregor and Fickling (1943) and Fairbank *et al* (1942) devised various types of external fixation appliances. Other appliances were developed by Stader (1937), Berry (1939), Haynes (1939) and Griffin (1941).

The present methods of external fixation of the fractured mandible are logical refinements of similar fixation techniques employed for the long bones; these will undoubtedly pass through a further developmental stage before attaining a permanent place in the treatment of mandibular fractures. Although the use of such fixation may often be indicated, the authors warn against the indiscriminate use of external skeletal fixation. Illustrations and roentgenograms of published case reports indicate that this type of immobilization has been employed when simpler procedures could have been used with greater assurance of achieving occlusal restoration.

The use of external fixation by means of pin appliances has been largely supplanted by the direct surgical approach and interosseous wiring of the fragments.

Indications for External Fixation

The use of such a method of reduction is justified in certain procedures:

1. For control of one, two or multiple edentulous fragments in early and delayed treatment of simple or compound mandibular fractures.

2. In fractures of the edentulous angle of the mandible when other methods fail to maintain reduction of the posterior fragment, particularly in order to control the mandibular angle in cases where the body of the mandible immediately anterior to the angle is severly comminuted or where loss of bone has occurred. Direct interosseous wiring cannot be employed in such cases.

3. For comminuted fracture of the mandible associated with fracture of the maxilla when dental appliances are not altogether satisfactory because of the loss of teeth.

4. When facilities for the construction of dental appliances are not available.

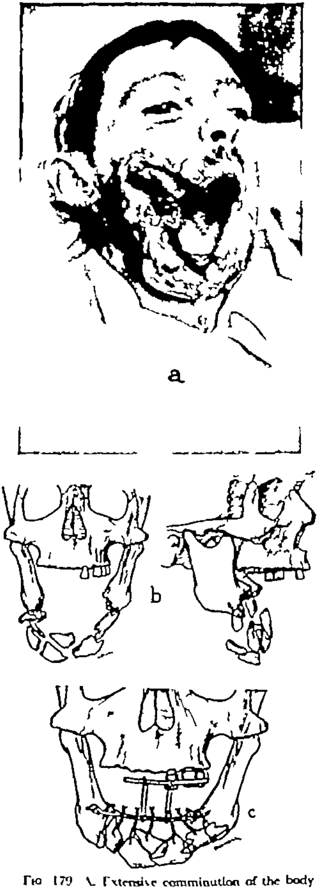

FIG 179 A. Extensive comminution of the body of the mandible resulting from gunshot wound with fragments of bone markedly displaced

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FIG 179.—*Continued*

B X-ray tracing of the body of the mandible prior to application of splints

C Fragments are suspended to a bar fastened to the main posterior fragment

border of the ramus on both sides was exposed through the oral wound. Extensive soft tissue damage of lip, chin or cheek tissue are concomitant factors.

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The use of such a method of reduction is justified in certain procedures:

1. For control of one, two or multiple edentulous fragments in early and delayed treatment of simple or compound mandibular fractures.

2. In fractures of the edentulous angle of the mandible when other methods fail to maintain reduction of the posterior fragment, particularly in order to control the mandibular angle in cases where the body of the mandible immediately anterior to the angle is severly comminuted or where loss of bone has occurred. Direct interosseous wiring cannot be employed in such cases.

3. For comminuted fracture of the mandible associated with fracture of the maxilla when dental appliances are not altogether satisfactory because of the loss of teeth.

4. When facilities for the construction of dental appliances are not available.

5 For the control of fragments following loss of bone substance or during reconstructive bone grafting

6 In rare cases, when wiring of the jaws is contraindicated.

External Fixation Technique

External fixation is conveniently performed under intratracheal anesthesia However inferior alveolar nerve block anesthesia can be used in conjunction with local infiltration of the soft tissues through which the pins of the external fixation appliance will penetrate The procedure is performed by two operators one manipulates the fragments intra-orally to obtain reduction (Fig 180) the other pins the fragments, maintaining sterile technique.

The site of the fracture is marked on the skin after the fragments are brought into alignment and two ink dots are placed over each fragment to indicate the point of entry for the pins (Fig 181) Two pins are placed in each fragment (Fig 182) each pin converging with its twin at an angle of about 70 degrees. The pins are usually inserted side by side along a line parallel

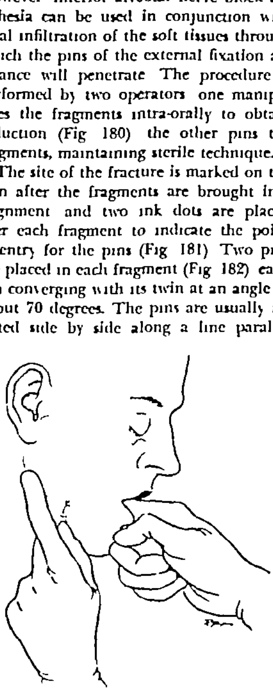

Fig 180 External fixation in fracture of edentulous mandible Reduction of fracture and alignment of fragment

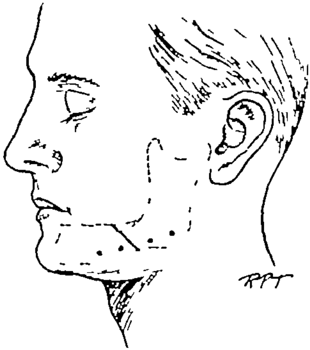

Fig 181 Site of fracture and points for insertion of pins marked in ink.

with the lower border of the mandible they are occasionally placed one above the other in the angle or ramus of the mandible (Fig 183)

The external maxillary artery and anterior facial vein should be avoided when inserting the pins through the soft tissues (Fig 181) the anterior border of the masseter muscle is a landmark for these vessels. The parotid gland must be avoided when pins are introduced into the ascending ramus. Penetration of the inferior alveolar nerve causes severe pain necessitating the removal of the pin.

Each pin is carefully inserted through the skin and soft tissues to the bone and is then drilled into the bone Resistance is encountered when the cortex is being traversed the pin penetrates the cancellous structure more readily Drilling is continued until the pin has penetrated the inner cortex (Fig 185). A similar procedure is repeated for each pin The bony fragments are held in apposition by the assistant during the entire procedure The connecting portion of the appliance is then adjusted and the joints are locked (Figs. 182 186).

The size of the stainless steel Kirschner wire generally used is 2 mm in width 1 mm pins can be used in some cases Finer pins cause less reaction of the soft tissues. The pins must be highly tempered and sharpened in order that the points penetrate the bone.

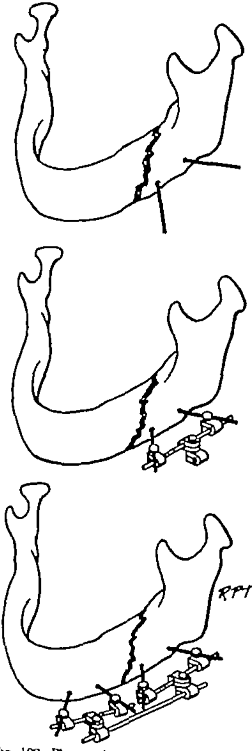

Fig. 182 Pins are inserted along a horizontal line and the connecting parts of the appliance are adjusted and the joints locked.

Fig 183 Photograph showing external fixation appliance in position. (Courtesy of the Tower Co.)

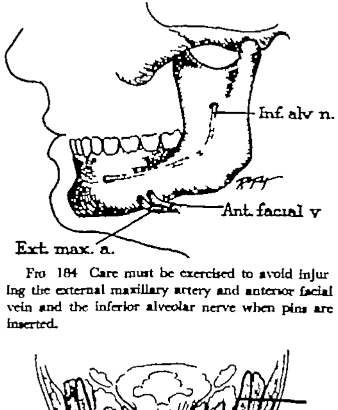

Fig 184 Care must be exercised to avoid injuring the external maxillary artery and anterior facial vein and the inferior alveolar nerve when pins are inserted.

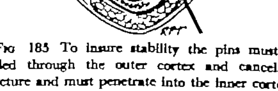

Fig 185 To insure stability the pins must be drilled through the outer cortex and cancellous structure and must penetrate into the inner cortex.

A small hand drill (Fig 187) is the most practical instrument. Friction-heat necrosis of the bone has been attributed to high speed revolutions of the electric drill dull

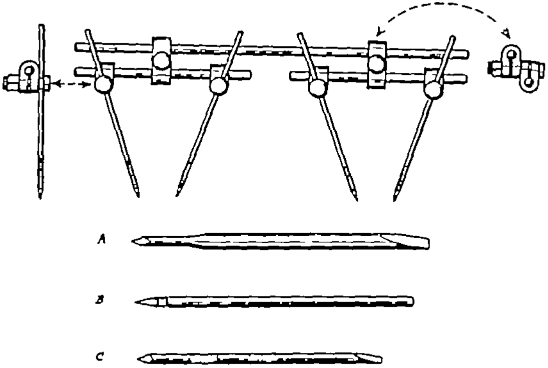

FIG 186. Drawing of external fixation appliance

A B and C show different types of pins used.
B The pin may be threaded and slowly screwed into position by hand after its insertion.
C. The depth of penetration of the pin is indicated by the two unpolished areas.

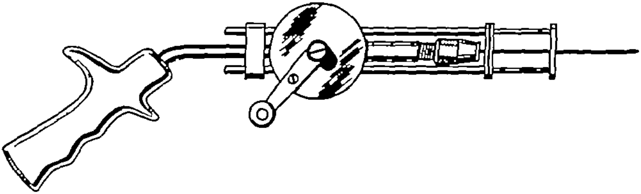

FIG 187 Hand drill for insertion of external fixation pins

ness of the points of the pins is a factor in the production of such heat necrosis (Anderson and Finlayson 1913) The ends of the pins can be threaded and carefully screwed into place by hand (Fig 188).

Complications Associated With External Fixation

INFECTION Because sterile technique and avoidance of contact with the oral cavity is an important consideration in this procedure the patient should be warned not to touch the pins or the dressings. The symphysis of the mandible is a poor site for pin insertion for pin holes are exposed to contamination by saliva and food in this location and the dense fat pad of the chin which must be transpierced offers little resistance to infection If external fixation is to be used in this region the pins should be placed on each side of the fat pad or introduced obliquely into the

lower border of the mandible to avoid both the fat pad and the roots of the teeth.

Edema should be differentiated from the firm mass of a hematoma Hematoma if transpierced by the pins, may result in infection the pins therefore should be inserted at a distance from the swelling (Converse, 1948)

ULCERATION OF THE SKIN The skin may be stretched and twisted when the pin unit is employed to reduce displacement of a fragment the pressure required to hold the fragments in place leads to ulceration and infection It must be emphasized that the external pin fixation method as its name implies, is intended for fixation primarily and not for reduction Minor adjustments in the relationship of fragments may be made after the appliance is in place.

FAULTY INSERTION OF PINS. An improperly inserted pin may become loosened, resulting in loss of both the pin and a fragment of bone. Each pin must be drilled through the outer cortex and the medulla into the inner cortex to achieve stability

FAILURE TO IMPACT THE FRAGMENTS. External fixation may not only retain the fragments in impaction but may also fix them in distraction a frequent cause of failure. Firm impaction must be assured before locking the connecting rod between the pin units. Complications include penetration of the root of a tooth or of the inferior alveolar canal Penetration of the parotid gland is often followed by salivary seepage around the pins this, however usually ceases in a few days or following removal of the pins.

External Fixation in Comminuted Fractures

Each fragment can be held by one converging pin unit in comminuted fractures the different units are retained by the connecting appliance.

In edentulous compound fractures of the mandible, associated with loss of bone external fixation can be employed to im

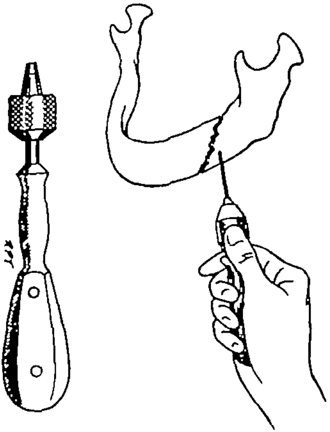

Fig 188 Handle for insertion of threaded screws

mobilize the fragments and preserve the anatomical position of the remaining fragments. The pins should be placed at a distance from the external wound to avoid interference with it (Fig 189)

External fixation is a useful procedure for controlling the posterior edentulous fragment in compound mandibular fractures associated with loss of bone but should be supplemented by intermaxillary fixation when possible. Figure 190 illustrates a case in which the right side of the body of the mandible was destroyed by a shell fragment Figure 191 is a photograph of a Moroccan soldier treated in North Africa during World War II with an injury similar to that shown in Figure 190 The teeth of the anterior fragment are utilized as anchorages for an intermaxillary appliance the posterior fragment is maintained by external fixation, with the pin unit connected anteriorly to the intra-oral appliance.

Fig 189 External fixation in compound fracture of mandible

(*Left*) German prisoner with compound fracture of the body of edentulous mandible Fragments immobilized by external fixation appliance

(*Right*) Dressing has been applied to the wound of the compound fracture

(J M Converse, Am J Orthodontics and Oral Surg 31 111 1945)

Fig 190 Diagrams showing a fracture of the mandible in which a portion of the body of the mandible is missing The reduction of the fracture was accomplished by the use of a banded appliance (A) with a vulcanite sleeve (B) and two external fixation pins fastened to the loose ramus (C) On the right the external fixation appliance is shown, fastened to the dental splint by means of the sleeve and the converging pins Bone rarefaction around the pins, caused by electric currents between the two metals, is avoided by the use of the insulating sleeve (B)

Fig 191 Photograph of patient with fixation appliance illustrated in Figure 190

COMPLICATIONS IN MANDIBULAR FRACTURES

Early Complications

Early complications following fractures of the mandible include primary hemorrhage, respiratory complications, infection avascular necrosis of the denuded bone osteitis osteomyelitis and trismus.

Primary Hemorrhage

When the injury is limited to the bone and does not involve the soft tissues primary hemorrhage in the majority of fractures is rarely profuse and usually ceases spontaneously Combined bone and soft tissue injury may result in considerable loss of blood. Treatment consists of clamping the bleeding vessels or if this fails, packing the wound.

Respiratory Complications

Respiratory obstruction may occasionally occur in severe fractures and is usually relieved by protraction of the tongue. Tracheotomy may be required in comminuted fractures. Intermaxillary fixation interferes with respiration in patients who develop postoperative bronchitis or pulmonary collapse or who have nasal obstruction. The intermaxillary wiring must be removed and the movements of the mandible restored in rare cases An airway is obtained with a nasopharyngeal tube lubricated with 2 per cent Nupercaine ointment placed for 48 hours large bore rubber tubes are placed in each buccal sulcus. A satisfactory air inflow is usually obtained by using these methods, removal of the intermaxillary fixation being a rare necessity in order to obtain a good airway The patient is taught to perform regular breathing exercises to prevent atelectasis.

Infection

Infection of the fracture site may appear early as a result of a number of conditions these include inadequate immobilization of fragments, the presence of foreign bodies in the wound, teeth in the line of fracture associated soft tissue wounds or preoperative disease Antibiotics are essential in the treatment of any bone infection

INADEQUATE IMMOBILIZATION. Early immobilization of the fracture favors resistance to infection. When the fracture is not immobilized, the young granulation tissue is repeatedly torn by constant displacement of the ends of the fractured bone, thus interfering with the healing process.

FOREIGN BODIES. Although foreign bodies may be tolerated by the soft tissues for long periods, infection may eventually occur; *this is especially true when the wound* contains particles of glass or fractured teeth. Removal of foreign bodies, an initial procedure in early treatment of the fracture, is a safeguard against the spread of infection.

TEETH IN THE LINE OF FRACTURE. A diversity of opinion exists regarding the preservation of teeth in the area of the fracture. The authors feel that attempts should be made to preserve teeth and even the roots of teeth, for they act as points of anchorage for splints. When teeth or roots are involved in the line of fracture, however, they become a potential source of infection (Figs. 192, 193). Abscesses occurring in jaw fractures are usually the result of retained teeth which have been deprived of their blood supply. The dental pulp degenerates in devitalized teeth and may then be invaded by bacteria. The risk in preserving a tooth of doubtful vitality is greater than that incurred in extracting the tooth. *There are some exceptions to this* rule. An injured tooth in a posterior fragment may be used temporarily for the purpose of reduction and fixation in displacement, but should be examined frequently; if the slightest symptoms of tenderness and swelling appear in the gingival or submaxillary regions, the tooth should be removed immediately (Fig. 191).

The antibiotics have made possible the temporary retention of teeth in the line of fracture until they have served the purpose of immobilization or until they may be re-

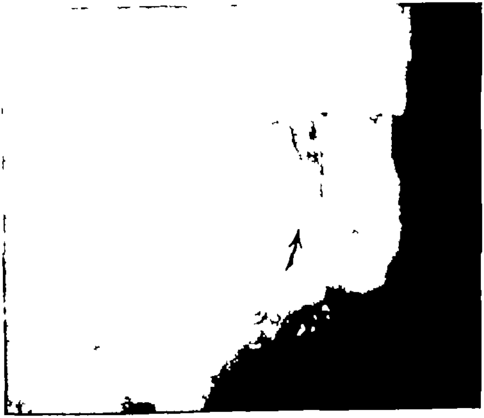

FIG. 19[illegible]. Roentgenogram showing fracture of lower jaw in the bicuspid region. The presence of isolated fragments and a tooth deprived of its bony support are potential sources of infection.

FIG 193. Roentgenogram of patient who was seen seven weeks after injury Examination revealed two suppurating sinuses at the right and left submaxillary regions and bilateral fractures of the body of the mandible, with teeth and sequestra in the lines of fracture This is a good example of infection caused by a tooth in the line of fracture. When the involved teeth and sequestra were removed the suppuration ceased. In this case it was eventually necessary to transplant bone to effect consolidation of the fracture of the mandible.

moved under favorable conditions. Even temporary retention of devitalized teeth, however is a risky venture.

PRESENCE OF SOFT TISSUE WOUNDS. External wounds and lacerations of the mucosa are points of entry for bacterial organisms. Compound fractures of the body of the mandible nearly always communicate with the oral cavity but usually heal readily unless the fragments are loose or foreign bodies precipitate infection.

PRE EXISTING PATHOLOGIC CHANGES. In rare instances infection following fracture originates from pre-existing disease in the mandible, such as a cyst or an abscessed tooth A low grade infection may flare up under the influence of added trauma

Treatment of Infection

Efficient treatment is necessary to prevent early infection in the form of abscess or bone infection Treatment consists of bed rest, forcing of fluids and administration of antibiotic therapy if the symptoms indicate acute infection. Local treatment consists of warm intra-oral irrigations, external hot saline compresses and especially immobilization of fragments

FIG. 194. Roentgenogram showing mandibular fracture with a tooth in the posterior fragment. The tooth was retained temporarily to aid in the fixation of the fragments but was removed when evidence of infection was detected.

The majority of early infections following injury subside with adequate treatment. The formation of an abscess is usually indicated by persistent symptoms and *increased swelling in the submaxillary or* sublingual region. Treatment should be continued until fluctuation appears either beneath the skin or the intra-oral mucosa. The abscess, when fluctuant, is incised at its most dependent point beneath the lower border of the mandible. The skin incision is made parallel to a skin fold in order that the resulting scar will be inconspicuous. *Incision and drainage should be post*poned until the abscess is localized and fluctuant. The causes of infection should be removed when the acute period of infection has subsided; further immobilization of the fragments should be secured, foreign bodies removed, and devitalized teeth in the fracture line extracted. It is important, however, not to attempt to remove teeth during the acute stage of the infection. Such operations in the acute phase are contraindicated.

Avascular Necrosis and Osteitis of Denuded Bone

Necrosis of denuded bone due to insufficient blood supply is followed by sequestration, elimination of bone fragments and secondary infection. The devitalized bone constitutes a foreign body and is a medium for the growth of organisms. The blood supply to the bone is inadequate when bone fragments are isolated from their soft tissue covering; infection, suppuration and sequestration may ensue. The need for early covering of bone fragments by soft tissues was demonstrated in World War II. In compound fractures of the leg in which a portion of the tibia was denuded of soft tissues, the early covering of the exposed bone by a pedicled flap not only prevented aseptic necrosis of bone and secondary osteitis but also insured the consolidation of the fracture. These same principles apply to the mandible. To prevent the massive loss of bone the procedure should be initiated as soon as the remainder of the mandible is immobilized and

after foreign bodies and devitalized tissue have been removed.

Traumatic avulsion of the soft tissues over the mandible results in devitalization of the cortex. A flap usually a locally rotated pedicled flap should be employed as a cover for the bone as early as possible for without this protection the bone is subjected to aseptic necrosis secondary infection and osteitis. The outer cortex of the bone is resected before applying the pedicled flap

Osteomyelitis of the Mandible

Osteomyelitis of the mandible is uncommon following simple types of fractures but has occurred more frequently following severely comminuted fractures, and especially compound comminuted fractures associated with soft tissue destruction It may be the aftermath of improper early treatment of the fracture.

Diffuse osteomyelitis of the mandible rarely occurs as the result of fracture. Localized osteitis is a more frequent occurrence.

Infection of bone should be suspected even after incision and drainage of an abscess if the symptoms are persistent if the patient continues to complain of pain if suppuration does not cease if redness and edema persist or the patient's temperature rises again following the incision of the abscess. The causes should be sought and remedied In addition to local treatment, the patient's general condition and nutritional status should be improved and antibiotic therapy should be increased.

Removel of sequestra should be planned when revealed by probing and by roentgenograms. The lateral aspect of the mandible is exposed through a submandibular incision and the sequestra are removed The soft tissue wound is then closed leaving a drain at one end of the incision line Complete immobilization of the mandible should be assured to assist the healing process.

Secondary Hemorrhage

Late hemorrhage resulting from fractures of the facial bones is a serious complication following gunshot wounds, especially those of the lower part of the face and occurs most frequently about the fourth to twelfth day after injury

The source of secondary hemorrhage is sometimes difficult to determine but the location of the entry and exit wounds in relation to the anatomical location of the blood vessels may be used as a guide. Injuries of the middle portion of the face often cause nasal bleeding probably originating from the sphenopalatine and descending palatine arteries. In open wounds with extensive injury of the soft tissues, hemorrhage is not usually a serious problem because the exposed bleeding point can be located and controlled by ligation or packing The external maxillary inferior alveolar and lingual arteries and their branches are the probable sources of hemorrhage in injuries of the lower portion of the face

The external maxillary artery can be controlled by ligation at the point of bleeding This vessel is often injured in wounds of the side of the face and the mucosa of the cheek. Hemorrhage from the inferior alveolar artery occurs infrequently but is seldom serious It is usually associated with comminution of the angle of the mandible

The lingual artery is usually the source of bleeding occurring as a result of an extensive wound in the mandibular molar region with accompanying injury to the floor of the mouth and tongue.

The base of the tongue is usually perforated and is greatly swollen and the mandible is fractured bilaterally in gunshot wounds when a missile passes through the floor of the mouth

Secondary hemorrhage also occurs in infected cases. Control of infection therefore, is the best prophylaxis against secondary hemorrhage It is particularly important to

provide fixation for inadequately immobilized compound mandibular fractures, for secondary hemorrhage is most frequent in such cases.

The slightest seepage of blood from wounds of the face and jaw demands immediate attention. Although the bleeding may appear quite harmless at first, most hemorrhages start with slight oozing of blood and such a seepage may continue for hours, eventually resulting in profuse hemorrhage.

Immediate arrest of the bleeding is accomplished by hydrogen peroxide irrigation, the removal of clots, and packing the wound. The retention of a packing in the floor of the mouth is facilitated by the use of a clamp, which is devised to fit the condition.

The external carotid artery on the bleeding side requires ligation when simple means fail to control bleeding in severe cases of secondary hemorrhage. Blood replacement is essential for any patient who has had severe bleeding.

Trismus and Ankylosis

Inability to open the mouth is a frequent occurrence in mandibular fractures as a result of pain, edema and spasmodic contriction of the muscles of mastication. Trismus is usually not severe and the jaws may be separated for intra-oral manipulations after adequate sedation. A spasmodic type of constriction of the jaws may occur, resisting attempts to separate the jaws for the introduction of intra-oral wiring or dental appliances. These conditions can be relieved under general anesthesia, or an injection of novocaine and hyaluronidase around the masseteric nerve and the nerves distributed to the temporalis muscle. This often results in relief of the spasm, enabling the patient to open his mouth.

Movements of the temporomandibular joint may be restricted due to disease in or around the joint. Intra-articular injury is a frequent accompaniment of mandibular fractures. Fracture of the neck of the condyle with displacement of the condyle may have occurred. The joint capsule of the articular disk may also have been injured. Scars, which result from injury, are often extra-articular causes of temporomandibular ankylosis.

Late Complications

Delayed union, non-union, malunion, trismus and ankylosis of the temporomandibular joints, scar adhesions of the oral tissues, inferior alveolar anesthesia and concomitant deformities are late complications in mandibular fractures.

Delayed Union

Delayed healing is common in compound, comminuted fractures and occasionally occurs in linear fractures when associated with chronic infection. This is usually due to inadequate immobilization or the presence of a foreign body. Consolidation is rapid in most cases after the source of infection is removed, provided the loss of bone from infection is not extensive.

Even in the absence of the above mentioned factors, slight mobility of the fragments may occur occasionally after a long period of intermaxillary fixation. The authors have observed rapid consolidation in such cases after intermaxillary wires have been removed and the jaw again permitted to function.

Delayed Reduction of Mandibular Fractures

Treatment is initiated late in neglected fractures of the mandible or in inadequately reduced fractures. Treatment of the fracture may have been overlooked and neglected because of more serious concomitant injuries. An unreduced fracture treated during the first three weeks after injury is in the process of consolidation with the fragments in a faulty position; the young osteoid tissue between the fragments is still malleable. It is often possible to exert grad

ual traction on the fragments by means of intra-oral arch bars, bands and elastics in order to align them. Attempts at progressive reduction may be both painful and unsuccessful when displacement is marked when consolidation is already beginning and in fractures of the angle with gross displacement.

In delayed reduction, when alignment of the fragments is difficult because of fibrous adhesions, the fragments should be loosened with a periosteal elevator under anesthesia in order to facilitate reduction When consolidation is more advanced, it is advisable to undertake open reduction by cutting through the newly formed bone tissue between the fragments and re aligning them. Fixation is assured by banded retention appliances in fractures of the body or by direct interosseous wiring in edentulous cases and in fractures involving the angle It is not so much the callus formed between the fragments that offers resistance to reduction in these cases as the contraction of the muscles. Open reduction and wide subperiosteal elevation of the muscles eliminates muscle pull the displaced fragments may then be manipulated into correct alignment.

Non aligned infected fractures present a special problem. Progressive elastic traction may improve the position of the fragments in the presence of infection open reduction however is contraindicated. It is essential to treat the infection and in some cases to allow consolidation to occur before undertaking a secondary osteotomy

Non union

Delayed union may result in non-union because of loss of bone or faulty alignment of fragments Loss of bone may occur in the initial injury or may result from infection followed by osteomyelitis and sequestration. Faulty alignment of the fragments often occurs in fractures near the angle of the mandible, where control of the posterior fragment is difficult Non consolidation of a fracture may also result from the improper use of fixation appliances. When rigid cast splints are used the surgeon may not be aware of the necessity for obtaining good occlusal relationships of the teeth or that the splint is causing separation of the fragments rather than drawing the fragments together

The impetus for osteogenesis, which is rapid in the early stages, decreases slowly if conditions are unfavorable for consolidation of the fracture the collagen fibers laid down by the osteoblasts form adult fibrous tissue instead of contributing to the formation of osteoid tissue. The scar tissue between the ends of the bones prevents the infiltration of osteoblasts and the deposition of calcium The ends of the bones become rounded and are gradually separated by the intervening fibrous tissue.

Consolidation of a delayed union in mandibular fracture can occur without surgical interference but after typical non union has developed surgical intervention is essential The operation consists of exposing the ends of the non united fragments, removing the intervening scar tissue freshening the bone edges, and re-establishing bony continuity by approximation of the fragments and maintenance of contact by direct interosseous wiring or preferably by re-establishing continuity with a bone graft When there is no deficiency of bone and when the loss of bony contact is essentially due to displacement by muscular action such as in unfavorable fractures of the mandibular angle, a small incision at the angle exposes the bony fragments and permits the manipulation of the displaced fragment into its anatomical position after the fibrous tissue between the fragments is removed. Drill holes can then be placed in the fragments and a wire suture used to maintain the fragments (see Fig 153) If difficulty is encountered in reducing the displaced fragment because of muscle contraction wide subperiosteal elevation around the fragment releases the muscle

pull both on the medial and lateral aspect of the angular fragment.

Bone grafts are often necessary to promote osteogenesis in the area Rounded eburnated ends of fragments should be freshened by cutting the ends. This precludes approximation of the bone edges without disturbing the occlusal relationships of the teeth the use of bone grafts is therefore necessary For small defects chips of bone are removed from the inner aspect of the lower border of the mandible adjacent to the defect and packed into the defect after the bone edges have been freshened It is usually necessary to employ a bone graft that consists mainly of cancellous iliac bone which extends between the ends of the non-united fragments and is also applied over the bone segment as an onlay graft. Strict immobilization must be obtained during a consolidation period of more than four weeks.

Malunion

Malunion results from absence of adequate immobilization and alignment of fragments. The malunion of the fragments may be due to only a rotation of the fragments, or the overlapping of fragments may shorten the mandibular arch. Malunion may have occurred after vertical displacement of fragments, resulting in an open bite on one side. Fragments may have become malunited after loss of bony tissue causing a change in the shape of the mandibular arch and malocclusion. Diagnosis may be difficult in multiple fractures, both mandible and maxilla being malunited, or because of the absence of structures normally serving as a guide A study of the dental casts and the cephalogram is of assistance. If the fragments are in malposition without loss of mandibular bone the fractured area is exposed intra-orally or by the external route the overriding sections are wedged apart and the fractured bone surfaces freshened. The fragments are realigned approximated and immobilized by intra-oral fixation appliances (Fig 193) direct interosseous wire fixation is used in the edentulous mandible. Further considerations on malunited mandibular fractures will be found in Chapter 24

Late Trismus and Ankylosis

A degree of stiffness which limits mobility is incurred after a long period of jaw immobilization this disappears gradually Scars often remain following reconstruction of the soft tissues of the cheek, the tissues not being sufficiently flexible to permit normal opening and closing of the mouth Foreign bodies may be embedded in the muscles of mastication Pressure on the coronoid process from a depressed fracture of the zygomatic arch may contribute

Fig 193 (*Left*) Photograph showing displacement due to faulty reduction of a compound comminuted mandibular fracture

(*Right*) Proper reduction following bilateral section of the mandible and re-establishment of normal occlusal relations

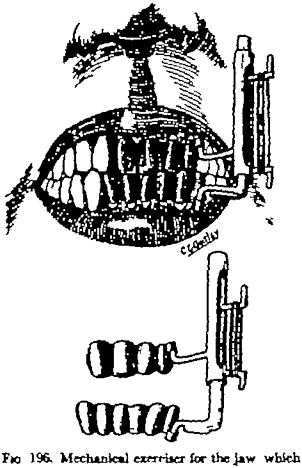

FIG 196. Mechanical exerciser for the jaw which works by the constant pull of elastic bands. The apparatus is attached over several lower front teeth by metal caps. It is used in cases of trismus of the jaw

(V H Kazanjian Surg Gynec. & Obst. 67 333 1938)

to the limitation of jaw movements. In addition to the downward displacement of the zygomatic arch, interference with movements of the coronoid process is sometimes due to a thickening of bone on the under surface of the zygoma as a result of subperiosteal hematoma following fracture. Permanent restriction of motion usually follows changes in or around the temporomandibular joint.

Mechanical dilators are sometimes useful to loosen scar tissues and adhesions (Darcissac 1921) (Figs. 196 to 198) Surgical intervention is necessary however in order to excise scar tissue and to supply an epithelial lining for the mucosa of the mouth, and to permit free movements of the jaw The removal of foreign bodies from masticatory muscles may be necessary

Pressure on the coronoid process from a malunited depressed fracture of the zygomatic arch is eliminated by raising the displaced fractured bone through the temporal route after osteotomy Resection of the coronoid process is an alternate method for relieving interference with mandibular function due to pressure over the coronoid

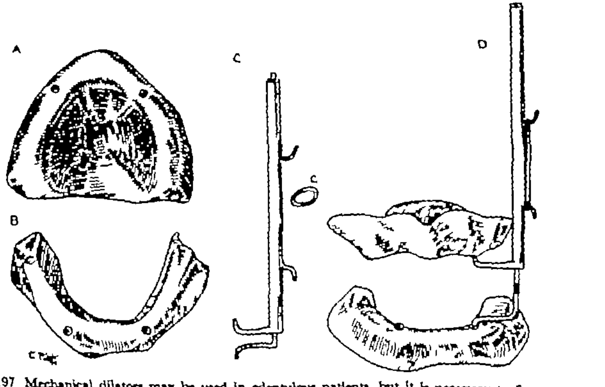

FIG 197 Mechanical dilators may be used in edentulous patients, but it is necessary to first construct special upper and lower base plates to fit over the alveolar ridges. These plates contain small holes at the upper and lower bicuspid region and the ends of the mechanical dilator fit accurately into these sockets.

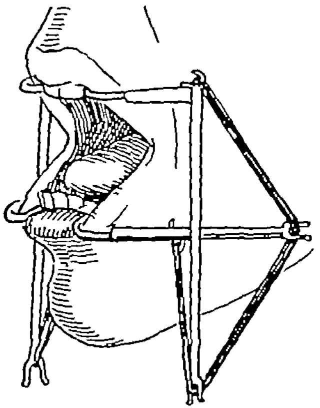

FIG 198. Darcissac exerciser employing bilateral elastic traction (after Aubry and Freidel 1952)

resulting from a malunited fracture of the zygoma

Mechanical devices are useless when there are permanent changes in the temporomandibular joint In such conditions condylectomy is indicated (see Chapter 26).

Inferior Alveolar Anesthesia

Loss of sensation in the area of distribution of the inferior alveolar nerve is a frequent occurrence in fractures which involve the body of the mandible Loss of nerve function is often due to compression by displaced fragments. Such pressure is relieved after proper re-alignment A section of the nerve may be destroyed or the nerve severed in compound fractures and in fractures with marked displacement and overriding of fragments. Inferior alveolar nerve anesthesia is permanent in defects of the mandible which have been repaired by bone grafting Restoration of function follows alignment of the fragments in most cases of nerve severance or compression Return of sensation is usually preceded by subjective symptoms often noted by the patient as a feeling of pins and needles in the area Some degree of impairment of sensation in the lower lip such as hypoesthesia or paresthesia is not an infrequent occurrence

Deformity

Restoration of the normal contour of the face follows re-alignment of the mandible in most mandibular fractures. In multiple fractures and in comminuted and in compound fractures, however loss of bone may be due to marked displacement of comminuted fragments or as a result of sequestration subsequent reconstructive surgery and bone grafting may be required in such cases to correct facial contour In condylar fractures some degree of deformity may be observed when the patient opens the mouth the condition being due to a shortened ramus lever No deformity is visible when the mouth is closed deviation of the chin to the affected side occurs when the mouth is opened Impairment of external pterygoid muscle function on the affected side contributes to the deviation

7

FRACTURES OF THE MAXILLA

Fractures of the maxilla are less common than those of the mandible the proportion is about one to four The maxilla is intimately associated with the skeletal framework of the face and also with some of the bones of the cranium These bones form a mass capable of resisting considerable violence, thus protecting the brain case. Without such a buffer there would assuredly be many more fatal head injuries.

ANATOMICAL CONSIDERATIONS

The maxilla is formed by the union of two symmetrical halves Each half is irregular in shape the hollow interior forms the maxillary sinus (Fig 199) The maxilla assists in the formation of the orbit nasal fossa oral cavity a large part of the palate a third of the floor of the orbit, the floor and outer wall of the nasal fossa and pyriform aperture and also supports the nasal bones and cartilages.

The maxilla is attached to the base of the skull by a series of buttresses (Cryer 1916) which are formed by neighboring bones (Fig 200) and is connected to the cranium above by the lateral walls of the interorbital space (Fig 201) This space is limited laterally by the medial walls of the orbits, anteriorly by the nasal processes of the maxilla and nasal bones, and posteriorly by the body of the sphenoid The ethmoidal air cells, upper part of the nasal fossae and nasolacrimal duct are contained within the interorbital space which is separated from the anterior fossa of the skull by the cribriform plate and the roof of the ethmoidal sinuses. The close association of the cribriform plate and the floor of the anterior fossa of the skull accounts for dural lacerations and brain damage which may result when severe injuries cause impaction of the maxilla or nasal bones into the interorbital space. The maxilla is flanked laterally by the zygomatic buttresses which connect it to the lateral sides of the skull The zygoma forms the lateral wall and floor of the orbit. Posteriorly the maxilla is attached to the base of the skull by the pterygoid processes of the sphenoid bone.

SURGICAL PATHOLOGY

An analysis of the skeletal anatomy of the middle portion of the face draws attention to areas of structural weakness. Their location and the common sites of fracture were determined in experiments conducted by LeFort (1901) (Fig 202)

The alveolar processes the vault of the palate and the pterygoid processes usually form a single detached block in lower maxillary fractures (Guerin s fracture or LeFort I) (Fig 203)

The nasal process of the frontal bone is relatively thick the upper portion of the nasal bones are narrow and thick above and wider and thinner below A transverse fracture line through the middle portion of the nasal bones at the junction between the thick and the thin portions of the nasal bones may extend through the frontal process of the maxilla cross the lacrimal bone double back through the orbital plate of the maxilla and infra-orbital margin de

FIG. 199 The maxilla Dotted area illustrates portion of the maxilla occupied by the maxillary sinus

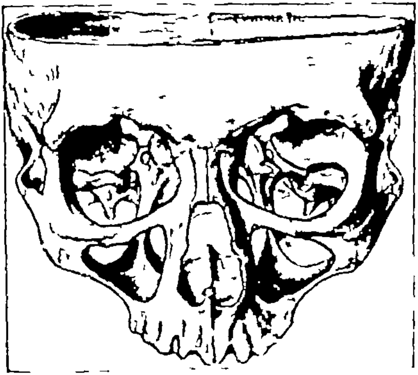

FIG. 200 Drawing of a dissected skull "The thinner bony portions have been removed leaving the heavier parts intact" (From H. H. Shapiro, *Maxillofacial Anatomy*, J. B. Lippincott Co. [illegible])

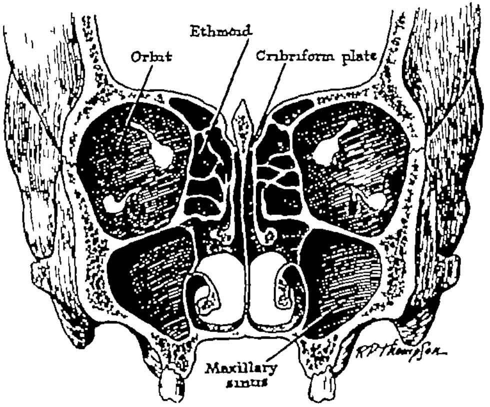

Fig 201 The interorbital space

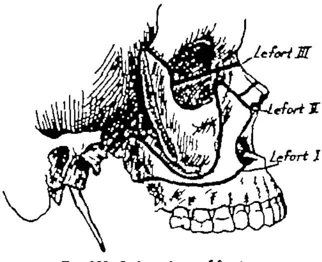

Fig. 202. Lefort's lines of fracture

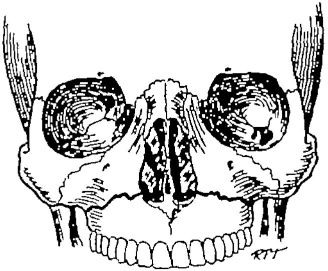

Fig 203 Guerin's fracture (Lefort I)

scend laterally through the anterior wall of the maxillary sinus near the zygomatico-maxillary junction across the posterior wall of the maxilla into the pterygomaxillary fissure, and through the pterygoid processes (LeFort II) This type of fracture is sometimes referred to as the pyramidal fracture (Fig 204) The interorbital space may be penetrated and splayed out in such fractures when associated with backward displacement

The pyramidal process of the maxilla and the zygoma may remain attached to the maxilla in high fractures (LeFort III) (Fig 205) the bones of the middle portion of the face being completely detached from the cranium at the level of the floor of the orbits. This type of fracture is termed craniofacial dysjunction

Maxillary fractures may also occur

concomitantly at two different horizontal levels

A sagittal or anterior posterior line of fracture is occasionally seen usually in association with a horizontal fracture. The fracture line is usually to one side of the mid line the bone is thinnest at this point (Fig 206)

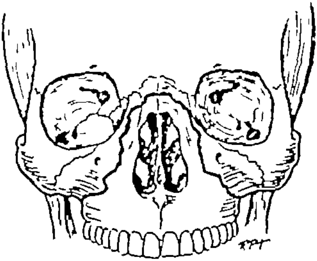

Fig 204 Transverse fracture of the maxilla extending through the nasal bones (Lefort II)

The alveolar processes constitute strong abutments on the lateral aspect of the hard palate the vomer reinforces the hard palate in the mid line immediately adjacent to the mid line however the palate is thin. The line of fracture may extend through the maxillary portion of the hard palate back through the horizontal portion of the palatine bone

The middle third of the face retains a degree of elasticity because of the pneumatization of the bones, considerable violence is necessary to detach the maxilla from the cranium. The maxilla unlike the mandible does not offer sites of origin to muscles sufficiently powerful to displace fragments, but serves as sites of bony origin only for the muscles of facial expression. Displacement therefore is less marked occurring downward laterally or downward and laterally and backward displacement with

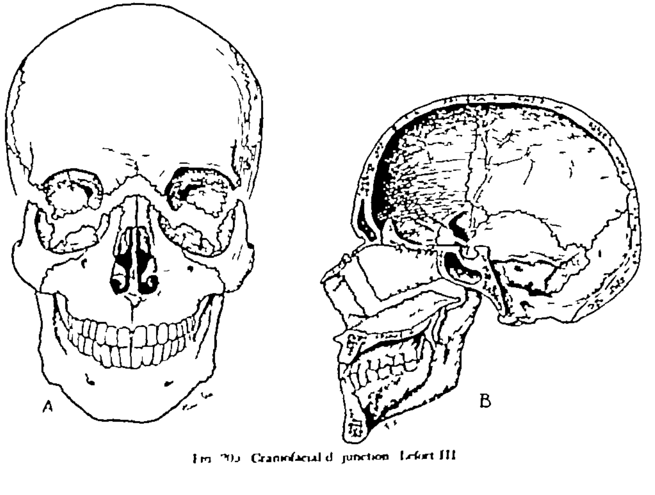

Fig 205 Craniofacial disjunction Lefort III

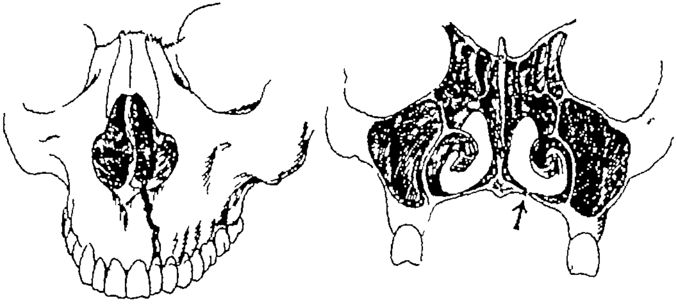

FIG. 206. Sagittal fractures of the maxilla usually occur through the thin portion of the hard palate situated laterally to the vomer

impaction seldom occurs in an upward direction A portion of the pterygoid processes may be detached with the maxilla from the base of the cranium in upper horizontal fractures.

In a loosened fractured maxilla the action of these muscles may be observed when the maxillary block is seen to move during deglutition (Dawson and Fordyce, 1953)

External pterygoid muscle action accounts in part for the backward displacement of the maxilla (Fig 207) The openbite often noted in these fractures may be due to the downward pull of the internal pterygoid muscle resulting in a backward tilting of the maxilla.

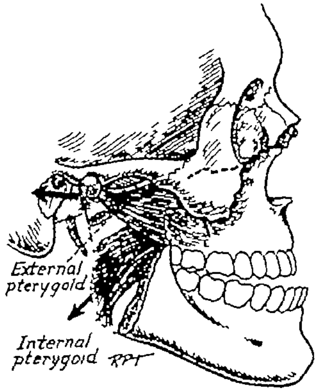

FIG 207 Pterygoid muscle action explains in part the backward displacement in upper maxillary fracture. The arrows show the direction of muscle pull

EXAMINATION AND DIAGNOSIS

Clinical Examination

The patient often presents a typical appearance with symmetrical swelling of the face bilateral orbital ecchymosis subconjunctival hemorrhage and swollen eyelids. When there is marked retroposition of the maxilla the face appears flat and longer or shorter than normal despite the swelling· an associated depressed zygomatic fracture may cause a depression of the orbital floor on one side Pain is felt when attempting to bite and failure of the upper and lower teeth to occlude may be noted by the patient who is rarely in a state of shock when the actual mass of tissue damage is small the presence of shock usually indicates associated lesions.

Bleeding from the nose is a common --

currence shortly after the injury but rarely necessitates emergency measures as the hemorrhage generally ceases spontaneously.

A discharge of cerebrospinal fluid from the nostrils or backward into the pharynx may be noted in high maxillary fractures when the cribiform plate is involved. Nasal deformity may be due to an associated nasal fracture.

Inspection of the teeth usually reveals disturbance in the occlusal relationships of the dentition. In complete transverse fractures when the displacement is only vertical and downward the teeth may meet in normal occlusion even though the entire maxilla is freely movable. Complete disarrangement of occlusion occurs, however, when the displacement is backward and downward or backward and upward, or when the maxilla is twisted laterally. Ecchymoses are usually seen in the upper buccal sulcus.

Irregularity of the central portion of the palate usually indicates fracture of the hard palate. A hematoma of the soft palate may also be noted.

A fractured maxilla may either be movable when pressure is exerted against the upper incisors, or immobile and firmly impacted. The bone is usually mobile and the middle portion of the face becomes slightly elongated due to the separation of fragments (Fig. 208). Swollen soft tissues may partially conceal this change of contour. The fracture may be impacted; this condition is usually manifested by an open bite.

In partial fractures which affect only one side of the maxilla and involve only the bicuspid and molar teeth, medial and inward displacement of the fragment prevents normal occlusion on the uninjured side (Fig. 209).

Palpation reveals mobility and crepita

FIG. 208. Elongation of the face caused by downward displacement of the maxilla in craniofacial disjunction.

tion at the site of fracture lines which may extend between the nasal or zygomatic bones and the maxilla Bimanual palpation elicits additional information By grasping the teeth and alveolar process between the thumb and forefinger of one hand movement may be felt by palpating the face with the fingers of the other hand

The infra-orbital margins are irregular in the LeFort II type indicating the site of the fracture if associated fractures of the zygoma are not present the LeFort I and III types have intact infra-orbital margins.

It is important, in maxillary fractures, to determine whether the fracture extends to the cranium A telescoping of the nose backward into the ethmoid associated with widening of the intercanthal distance may occur in severe crash injuries. Loss of consciousness, especially if prolonged indicates a probable cranial injury Hemorrhage from one or both ears is an almost certain sign of skull fracture although occasionally in association with fracture of the mandibular condyle tearing of the external auditory canal may account for bleeding Positive diagnosis of cerebrospinal rhinorrhea is evidence of cribriform plate involvement (see Chapter 10)

Roentgenographic Examination

The clinical diagnosis of maxillary fracture is verified by roentgenographic examination which reveals the direction of the fracture lines and also discloses unsuspected fractures of other bones of the middle portion of the mandible and of the skull (see Chapter 13)

TREATMENT

The general care of the patient is similar to that in mandibular fractures. Additional precautions however are necessary If fractures involving the fronto-ethmoidal region are suspected drastic manipulation of the fragments should be discarded in favor of simple, conservative methods Fractures of the maxillary bone heal quite readily

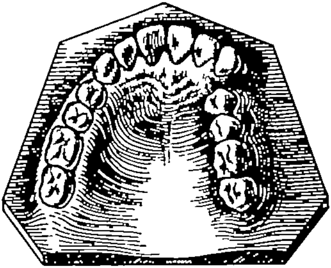

Fig 209 Displacement in partial fracture of the maxilla

reduction and immobilization therefore, should not be unduly delayed. The entire facial substructure may be so distorted in severe injuries, as to cause permanent deformity of the face unless treatment is adequate (Fig 210)

Emergency Measures

The mouth should be cleansed loose teeth or dentures removed and the patient placed in the prone position with the tongue drawn forward. The dorsum of the tongue may rest against the hard palate and the pharynx, obstructing the airway when the maxilla is displaced posteriorly A nasopharyngeal tube should be introduced when the possibility of such a condition exists. Transportation is a hazard in severe maxillary fractures tracheotomy before transportation may therefore be advisable.

Fractures of the maxilla can be classified according to the mechanical principles governing reduction and fixation of fragments, rather than to the level of the fracture line. Each maxillary fracture requires a specific method of immobilization based upon available points of anchorage for fixation appliances.

Treatment of the fractured maxilla consists of two procedures (1) the reduction of displaced fragments and their replacement

Fig. 210

(*Left*) Appearance of patient before the injury

(*Right*) Deformity resulting from unreduced fracture of maxilla with backward displacement. Note deepening of the nasolabial folds.

(V. H. Kazanjian, Am. J. Dent. A., 20: 757, 1933)

using the re-establishment of normal occlusal relationships as a guide and (2) the immobilization of the reduced fragments against the base of the cranium until consolidation occurs. Methods of achieving these results vary according to whether one is dealing with a partial or complete transverse fracture of the maxilla.

Partial Fractures of the Maxilla

Under this classification are grouped the various types of fractures in which a portion of the maxilla only is detached from the cranium. The fractured portion of the jaw may constitute either a small portion or a larger segment of this group; these involve the palate in addition to the alveolar processes, although the main segment of the maxilla remains intact.

The aim of reduction and fixation of fragments in partial fracture of the maxilla is the restoration of dental occlusion and the normal contour of the alveolar process and palate. Two guiding principles should be followed for this purpose: (1) the teeth of the nonfractured side of the maxilla are utilized for reduction and fixation of the fractured fragments, and (2) the teeth of the mandible are maintained in occlusion with those of the maxilla.

Utilization of Teeth for Anchorage on the Unaffected Side

Selection of the method of immobilization of fragments is dictated by the nature of the displacement and the teeth available for anchorage. Teeth to be utilized as anchors should be selected according to their ability to withstand the stress and strain of splinting and wiring.

Horizontal or Lateral Interdental Wiring

The fragment is usually displaced toward the palate in unilateral fracture of the maxilla; in such cases, the method given below is effective as a first aid procedure.

Brass or other alloyed metal wires of 23 gauge or stainless steel of 30 gauge are

twisted around the necks of two teeth on each side of the fracture line. One of the wires is passed around the bicuspid distal to the fracture line and brought to the buccal side between the teeth close to the fracture line (Fig 211) The teeth serve as points of leverage when the displaced fragment is forced into its proper position by digital pressure The wires on each side of the fracture are twisted together firmly to immobilize the fragments.

Intra-oral Retention Appliances

Metal bands are fitted over selected teeth on each side of the fragment these are bridged together with an arch bar similar to the appliance used for fractures of the mandible (Fig 212) The arch bar includes the teeth within the fractured area A banded appliance is useful for fixation of partial fractures of the maxilla retention splints are especially valuable in comminuted fractures in which the upper jaw is badly crushed.

The Teeth of the Maxilla are Maintained in Occlusion With Those of the Mandible

The fixation appliances described above for immobilization of partial fractures are designed to permit free movement of the mandible. Intermaxillary wiring is advisable, especially if the maxillary fracture is associated with a concomitant Class II fracture of the mandible Following immobilization of the maxillary fragment, further fixation is obtained by bringing the teeth into occlusion for the lower teeth help to press the fragment in place A figure-of eight Barton bandage maintains the jaws in occlusion (Fig 213) Headgears for this purpose are described elsewhere in this chapter

If the fracture line traverses the maxilla above the level of the apices of the teeth the bone surrounding the apices assures an adequate blood supply even though the fragment is severed from the rest of the maxilla these teeth should therefore be re

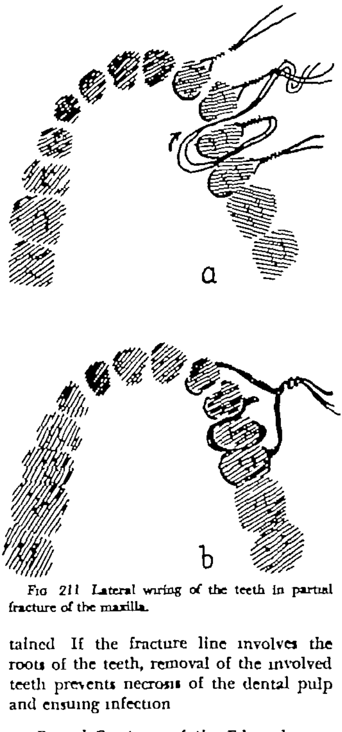

Fig 211 Lateral wiring of the teeth in partial fracture of the maxilla.

tained If the fracture line involves the roots of the teeth, removal of the involved teeth prevents necrosis of the dental pulp and ensuing infection

Partial Fractures of the Edentulous Maxilla

If the maxilla is edentulous the fragments may be immobilized by relining the patient s denture with dental compound or by means of an acrylic bite-block designed to occlude with the lower teeth. An external bandage or removable headgear maintains pressure of the lower teeth against the bite block. If the lower jaw is also edentulous, the bite block can be immobilized by an external attachment with cranial

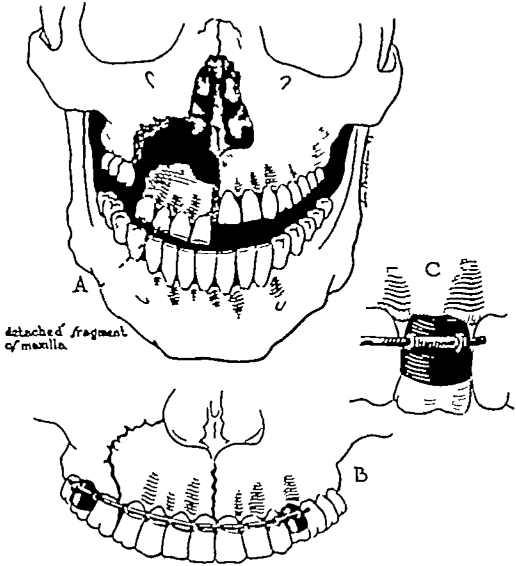

Fig. 212. Partial fracture of the maxilla immobilized by means of a retention splint. (J. M. Converse, J. Oral Surg. 3:112, 1945.)

fixation employing a Kingsley type splint. Wiring the upper denture to the inferior portion of the lateral border of the pyriform aperature may also be employed. Fixation of a lower denture may be obtained by means of circumferential wiring, an external bandage or headgear maintaining pressure of the lower denture against the upper denture.

Comminution of the alveolar bone and the palate in association with maxillary fracture should be treated similarly to fracture of the alveolar process with the aid of a bite block designed to support the surrounding soft tissues.

Complete Transverse Fractures of the Maxilla

A feature of the transverse fracture is the complete separation of the lower maxillary fragment from its attachments to the remainder of the maxilla, or the separation of the maxilla from the cranium. The line of fracture is generally horizontal and may be located at any of the various levels previously described. The fragmented segment may be separated and loose, the "floating" maxilla, or firmly impacted at the line of fracture.

Treatment is dictated mainly by the direction and degree of displacement. (1) In

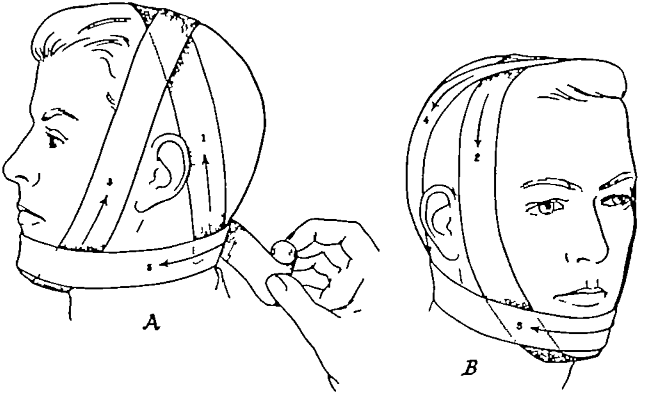

FIG 213 Application of the Barton bandage. Two-inch gauze or elastic bandage is used. A figure-of-eight is formed

A. Beginning in the occipital region, the bandage is continued diagonally upward to the other side of the face under the ear under the chin and returned to the other side in front of the ear back to the top of the head to the occipital region.

B. At this point it is carried horizontally in front of the chin to the opposite occipital region. The process is repeated until the entire bandage is used.

simple downward displacement when the patient brings the jaws together the teeth are again placed in normal occlusion (2) In lateral displacement of the fragment or when the maxilla is impacted backward the occlusion of the teeth is disturbed In the first type a simple Barton bandage suffices In the second type the treatment must be modified.

Fractures with Downward Vertical Displacement Only

In this type of maxillary fracture the re-establishment of adequate dental occlusion is the initial treatment, followed by immobilization of the maxilla against the cranium.

Because of the widespread use of plaster headcaps we wish to draw attention to relatively simpler means of immobilizing the maxilla Both the plaster headcap and the use of a Kingsley type appliance are uncomfortable for the patient. A simple method of cranial fixation for this type of fracture consists of placing sufficient pressure under the symphysis and lower border of the mandible to transmit pressure upon the mandible against the cranium with a simply constructed headgear providing that there are no soft tissue wounds in the lower portion of the face

CRANIAL FIXATION Upward pressure can be obtained by means of an elastic bandage or an ordinary surgical bandage combined with elastic bands. If the latter of these methods is used, a figure-of-eight Barton (1819) bandage (Fig 213) is applied and elastic bands are stretched over the bandage in front of the ear on both sides of the face and retained in position with adhesive tape

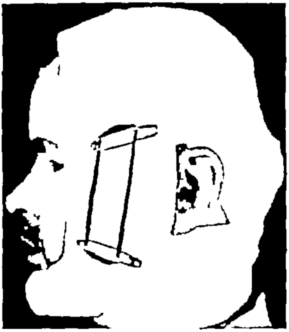

FIG 214 Elastic traction in combination with Barton bandage

(Fig 214) the elastic bands are easily adjusted to regulate upward pressure

A *semipermanent headgear and chin piece* may be constructed of one-inch woven cotton strapping material or ordinary adhesive tape Retention of a bandage or headgear is aided by enveloping the head with stockinette or a stockinette type material Both the headgear and the chin piece are provided with hooks or ordinary safety pins on the side of the face in front of the ears elastic bands are attached to these hooks to force the lower jaw against the upper (Fig 215) This type of headgear is readily adjusted and removed. A plaster headgear can also be used but should be bivalved and made readily removable (Fig 216) Because fractures of the maxilla heal readily maintenance of pressure by these simple methods for two or three weeks usually assures consolidation

Fractures with Downward and Backward or Lateral Displacement

These fractures are usually loose but may be impacted in cases of marked backward displacement The line of fracture usually extends through the nasal bones, diagonally through the floor of the orbit and downward and backward across the pterygoid processes of the sphenoid bone (Fig 217) The nasal and zygomatic bones may be fractured Fracture of the cribriform plate should also be suspected in this type of injury and the patient carefully observed for typical signs.

The condition of the patient does not always permit early reduction of these fractures. Failure to reduce the maxilla while the fragments are still loose may result in permanent changes in the contour and outline of the face Figure 218*A* illustrates a moderate backward displacement of the maxilla an unusual compound comminuted fracture of the maxilla with marked backward displacement is shown in Figure 218*B*

Most displaced maxillary fragments can be reduced by simple intermaxillary elastic traction using the re-establishment of the dental occlusion as a guide Reduction can be assisted by manual manipulation of the fragments. It is rarely necessary to resort to instrument manipulation when such fractures are treated early

Fixation of a fractured maxilla presents difficulties when other bones of the face are fractured concomitantly Associated depressed zygomatic components must often be elevated Impaction may occur deep to the zygomatic arch on one side when the maxilla is markedly displaced to one side and posteriorly It is necessary to disimpact the maxilla in such cases by drawing the entire maxilla to the opposite side and fixing it in relation to the correct occlusal relationship

REDUCTION OF POSTERIOR BACKWARD OR LATERAL DISPLACEMENT BY ELASTIC TRACTION Posterior and lateral displacement is corrected by elastic traction and downward displacement by external pressure with a head bandage Wire buttons or bands are placed around selected teeth usually the

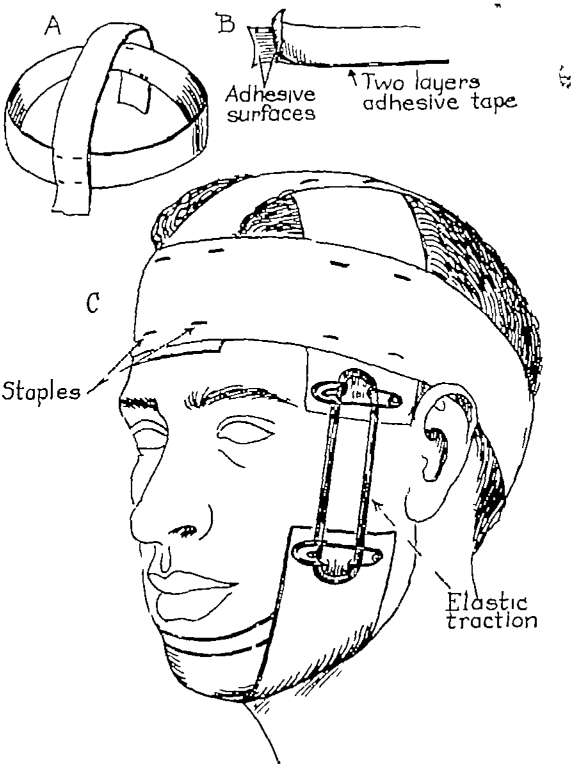

Fig 215 Headgear made of adhesive tape

A and B. Strips of adhesive tape are held together by stapling

C. Completed headgear with upward elastic traction.

posterior teeth in the lower jaw Elastic bands are applied to these Kazanjian buttons (Fig 219)

Reduction of anteroposterior displacement does not require a great deal of elastic traction the patient is barely aware of the force, the constant tension gives good results, and correct occlusion of the teeth is often attained within a relatively short period. The procedure is relatively painless and may be accomplished at the bedside without anesthesia. The anteropos-

FIG. 21C. Plaster headgear for maintaining upward pressure in fracture of the maxilla. The plaster has been bivalved allowing periodic removal of headcap.

terior displacement is reduced more readily if traction is applied early. Reduction of lateral displacement is accomplished in a similar manner while the anteroposterior displacement is being corrected. Added pressure is exerted on the deviated side by the addition of extra elastics between the buttons if necessary (Fig. 219B).

Elastic traction should be maintained for at least ten days following reduction; the premature release of the elastics may permit the fractured maxilla to slide back, gradually assuming a displaced position.

Cranial Fixation by Plaster Headcap

The simple headgear with elastic traction to maintain cranial fixation of the fractured maxilla by pressure exerted by way of the mandible has already been described, traction being exerted by upward pressure from under the chin. Many maxillary fractures, however, are complicated by injury to the soft tissues; in such cases pressure from below the chin is impractical and a plaster head-cap should be employed for cranial fixation of the maxilla.

CONSTRUCTION OF A HEADCAP. A satisfactory headcap for cranial fixation can be made of plaster, various attachments being incorporated in the plaster to support extensions from intra-oral and external appliances. Stockinette material is placed over the head (Fig. 220) and a layer of felt one-quarter of an inch (0.5 cm.) thick is placed over the forehead as a cushion. Two-inch (5 cm.) plaster bandage is moistened, wrapped around the forehead and extended around the head posteriorly below the occipital protuberance; the various fixation attachments are embedded in the plaster during this procedure. After a sufficient amount of plaster is applied, the free end of the stockinette is everted over the plaster to provide a smooth surface and the excess stockinette material is removed. The headcap need be only heavy enough for the purpose intended. Since the plaster must extend below the occipital protuberance for stabilization, the headcap should be cut through in the temporal area before the plaster sets to facilitate removal. Hooks are incorporated in the plaster; the separated headcap is thus held together with elastics.

After completion of the headcap a choice is made between two methods of immobilization. The first method is to force the mandible against the maxilla by means of a banded retention appliance attached to the lower teeth; this procedure is especially indicated when a concomitant fracture of the mandible necessitates the use of a metal splint.

The second method establishes direct cranial fixation of the maxilla by employing the Kingsley splint.

The Kingsley Splint

The Kingsley splint consists of an intra-oral appliance fitted over the upper teeth and sometimes the palate, with arms extending from the corners of the mouth parallel to the surface of the face and directed toward the ear lobes (Fig. 221). Kingsley (1880) described an appliance consisting of a vulcanite splint fitted over the teeth of the lower jaw with lateral projecting arms

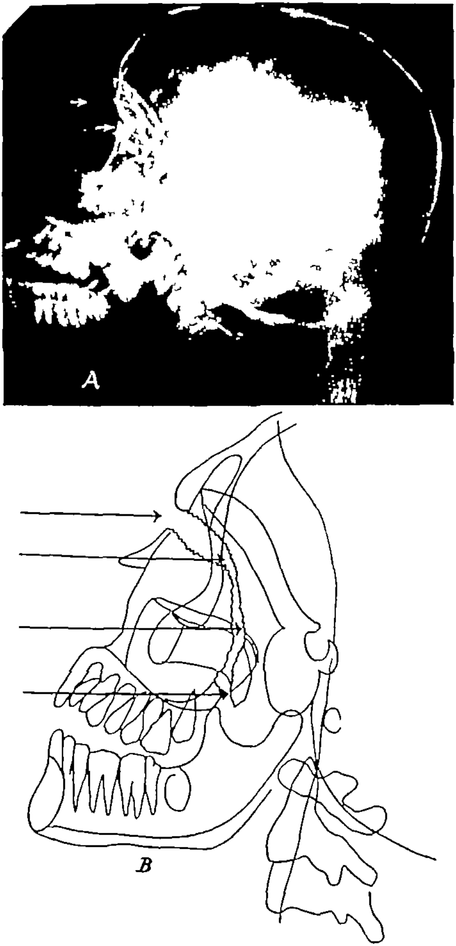

FIG 217 A. Roentgenogram showing craniofacial disjunction with backward and downward displacement of maxilla.

B. Tracing of roentgenogram showing lines of fracture.

(V H Kazanjian, J Am. Dent. A., 20 757 1933)

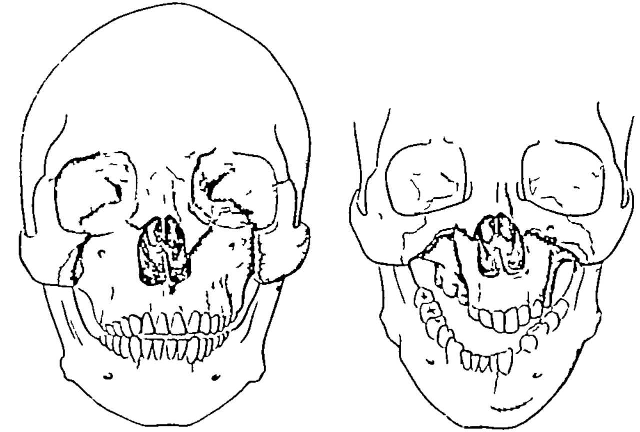

FIG. 218. (*Left*) Maxillary fracture with moderate backward displacement. (*Right*) Drawing from roentgenogram showing unusual fracture of the maxilla with marked backward displacement.

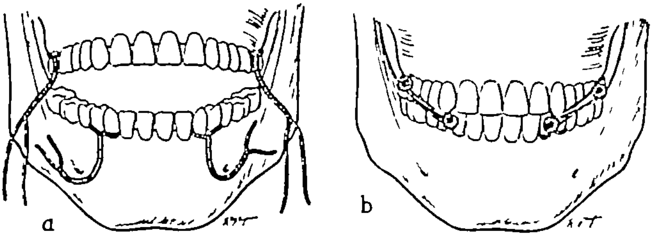

FIG. 219. A. Wiring of the teeth preliminary to application of elastics. B. Elastic bands applied for intermaxillary traction. When there is lateral displacement of the maxilla more elastic pressure is applied to the deviated side by placing an extra elastic band between the buttons.

which served to provide external fixation by means of a submandibular bandage. Later Kingsley adapted this splint for upper jaw fractures.

Elastic bands extend from the arm of the splint on each side to the headcap, thus exerting upward pressure against the maxilla (Fig. 222). The position and direction of the elastic bands is important. If pressure is exerted closer to the anterior part of the maxilla, an open bite may result; to prevent this, the traction is directed from the posterior portion of the arm of the appliance to the headcap.

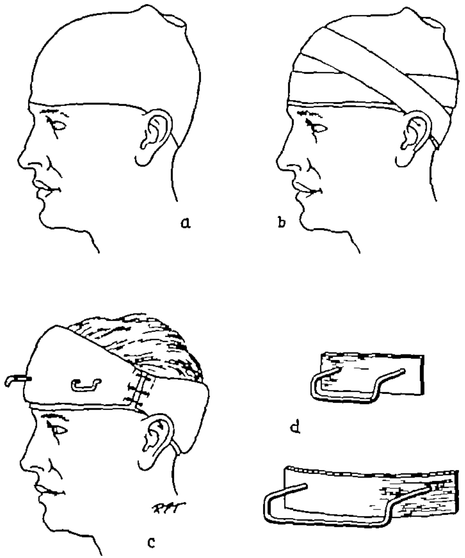

Fig 220 Method of constructing a plaster headcap

A. Stockinette placed over the head

B. A layer of felt, .5 cm thick, is placed over the forehead and moistened plaster bandage is then applied

C. Head cap completed

D Attachments incorporated in the bandage to anchor appliance for cranial fixation

When an intra-oral splint covers the biting surfaces of the teeth it interferes with proper occlusion and may eventually lead to malocclusion. This can be prevented by the use of a fenestrated splint which exposes the cusps of the teeth as shown in Figure 223 and permits the restoration of proper dental occlusion. Emphasis is placed upon the necessity for intermaxillary fixation in order to restore adequate dental occlusion maxillary fractures treated by cranial fixation with the Kingsley appliance, without intermaxillary fixation frequently result in malocclusion of the teeth

The Kingsley splint is usually employed for loose maxillary fractures. A modification employing Kirschner wires, can be used for the reduction of impacted fractures. The universal joints of an external fixation appliance (Fig 224) can be used to connect the lateral extensions from an upper dental splint to the cranial fixation apparatus by means of Kirschner wires (Fig 225) These stainless steel wires are resilient and are usually available in hospitals, being used by orthopedic surgeons they are manufactured in varying sizes. A controlled amount of force can be exerted to reduce an impacted fracture by bending the wires to a suitable curvature (Fig 226)

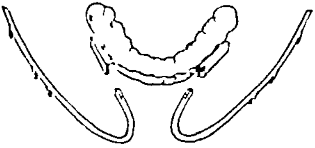

FIG. 221. The splint fits over the upper teeth and alveolar processes. The short arm of the side bar fits into a square tube on the splint; the long arm extends posteriorly from the corner of the mouth and is attached to the headcap by elastics.

FIG. 222. Patient with fracture of upper jaw. Kingsley splint is fitted over the alveolar processes and palate, with a bar extending from corners of mouth. Elastic bands extend from the headgear down to the bar, producing constant tension.

A greater degree of traction can be applied to one side than to the other by varying the position of the universal joints on the lateral attachments to the splint, and adjusting the curvature of each Kirschner wire. When reduction of the fragment has been obtained, the two lateral Kirschner wires are straightened, thus providing cranial fixation.

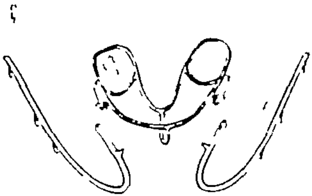

FIG. 223. Fenestrated splint for the maxilla. The wire splint is fitted to the dental arch leaving the cusps of the teeth exposed, thus permitting the restoration of the occlusal relationship of the teeth.

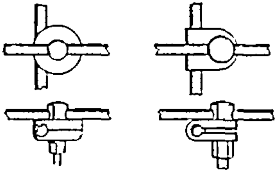

FIG. 224. Universal joints of an external fixation appliance which may be utilized for cranial fixation as shown in Figure 225.

Cranial Fixation by Interosseous Wiring

We have repeatedly emphasized the present trend toward the more frequent employment of open reduction and direct interosseous wiring in the treatment of comminuted fractures of the facial skeleton. This method, which offers a direct approach to the fracture site and positive control of the fragments, may be employed more frequently than formerly due to the protection afforded by antibiotics and modern techniques in anesthesia. At no time, however, should the surgeon lose sight of the need for the re-establishment of dental occlusion. Consolidation of maxillary fractures is a relatively simple problem; the correction of malocclusion following consolidation may involve complicated treatment.

Direct interosseous wiring at the frontozygomatic junction is a useful procedure in craniofacial dysjunction and in comminuted fractures (Figs 227 228) When the fracture line extends from the orbital rim downward and backward toward the pterygoid processes, and the downward displacement leaves a gap between fragments open reduction is accomplished through a small incision exposing the external rim of the orbit and the fractured area (Fig 229). Subperiosteal exposure of the bone on each side of the line of fracture permits drilling holes in the bone above and below the fractured area. Stainless steel is passed through the holes and the fractured surfaces are brought together by twisting the wires (Fig 228) the wire ends may remain buried indefinitely One should not depend upon this procedure alone however for while the upper end of the fractured bone is held securely on each side, the occlusal relation of the teeth is not controlled Intermaxillary wiring of the teeth of upper and lower jaws in correct dental occlusion is a prime requisite

Fixation of a fractured maxilla to the zygoma in Guerin s or in a pyramidal fracture (LeFort II) may be accomplished by means of stainless steel wire looped around a buccal arch bar in the molar region threaded through a Reverdin needle and brought up under the zygoma and through the skin over the temporal process of the zygoma (Adams, 1912) The needle carrying the wire is then placed through the same opening in the skin and looped around the outer aspect of the temporal process of the zygoma down to the molar region where the wires are then twisted together A variation of this procedure is to loop the wire through the interosseous wire suture previously placed to join the zygoma and frontal bone (Fig 227) A hazard in this method is caused by the obliquity of the wire when it is attached to the teeth too far anteriorly this results in a backward displacement and tilting of the fractured portion of the maxilla the wire loop must therefore be placed as nearly vertical as possible. Intermaxillary fixation is essential in all these cases to maintain correct dental occlusion

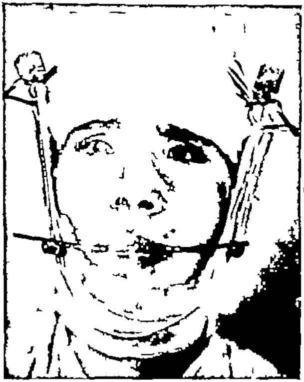

FIG 225. Kirschner wire apparatus for fixation of fractured maxilla as shown in Figure 226 The attachments are made with small universal joints shown in Figure 224

(Figs. 225 226 J M Converse, J Oral Surg 3 112, 1945)

Cranial Fixation by Wire Traction

Fixation of the fractured maxilla by traction exerted by wires passed through the cheek connecting the maxillary teeth to a headcap (Fig 230) is an additional procedure (Federspiel 1934)

A stainless steel wire using a standard lumbar puncture needle is passed through the cheek in front of the zygomatic prominence on each side. The entry site of the cheek wire is so placed that the wire passes in a straight line from the head cap to the maxillary appliance and approximates the point of least movement in the cheek, thereby avoiding subsequent cutting of the skin by the wire. These wires are at

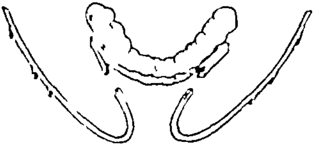

Fig. 1 The splint fits over the upper teeth and alveolar processes. The short arm of the side bar fits into a square tube on the splint; the long arm extends posteriorly from the corner of the mouth and is attached to the headcap by elastics.

Fig. 223 Fenestrated splint for the maxilla. The wire splint is fitted to the dental arch leaving the cusps of the teeth exposed, thus permitting the restoration of the occlusal relationship of the teeth.

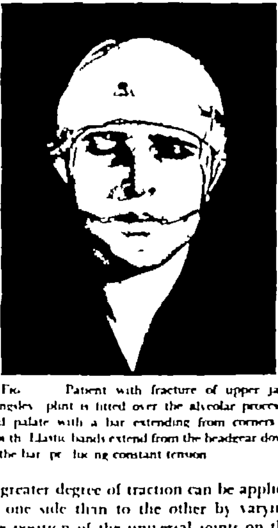

Fig. Patient with fracture of upper jaw. Kingsley splint is fitted over the alveolar processes and palate with a bar extending from corners of mouth. Elastic bands extend from the headgear down to the bar producing constant tension.

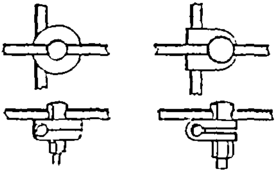

Fig. 1 Universal joints of an external fixation appliance which may be utilized for cranial fixation as shown in Figure 223.

A greater degree of traction can be applied to one side than to the other by varying the position of the universal joints on the lateral attachments to the splint and adjusting the curvature of each Kirschner wire. When reduction of the fragment has been obtained, the two lateral Kirschner wires are straightened, thus providing cranial fixation.

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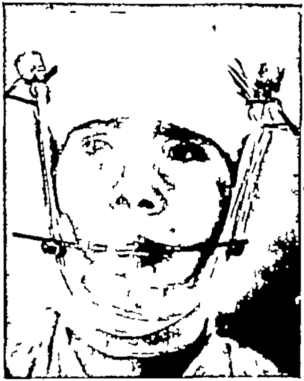

FIG 225 Kirschner wire apparatus for fixation of fractured maxilla as shown in Figure 226. The attachments are made with small universal joints shown in Figure 224

(Figs. 225 226 J M. Converse, J Oral Surg 3 112, 1945)

Cranial Fixation by Wire Traction

Fixation of the fractured maxilla by traction exerted by wires passed through the cheek connecting the maxillary teeth to a headcap (Fig 230) is an additional procedure (Federspiel 1934)

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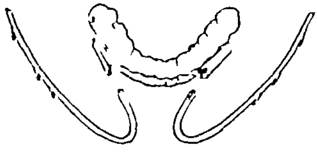

Fig. 221 The splint fits over the upper teeth and alveolar processes. The short arm of the side bar fits into a square tube on the splint; the long arm extends posteriorly from the corner of the mouth and is attached to the headcap by elastics.

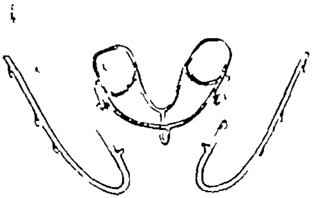

Fig. 223 Fenestrated splint for the maxilla. The wire splint is fitted to the dental arch leaving the cusps of the teeth exposed, thus permitting the restoration of the occlusal relationship of the teeth.

Fig. 222 Patient with fracture of upper jaw. Kingsley splint is fitted over the alveolar processes and palate with a bar extending from corners of mouth. Elastic bands extend from the headgear down to the bar producing constant tension.

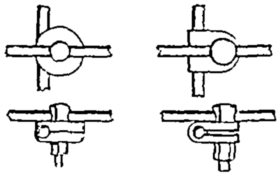

Fig. 224 Universal joints of an external fixation appliance which may be utilized for cranial fixation as shown in Figure 225.

A greater degree of traction can be applied to one side than to the other by varying the position of the universal joints on the lateral attachments to the splint and adjusting the curvature of each Kirschner wire. When reduction of the fragment has been obtained, the two lateral Kirschner wires are straightened, thus providing cranial fixation.

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Fig 228. Direct wiring for craniofacial dysjunction.

A. Roentgenogram showing high maxillary fracture.

B. Approximation of the frontozygomatic junction with stainless steel wire.

tached to wire loops, or to the arch bar of a banded intra-oral appliance in the first molar region, and to the lateral sides of frontal inserts in the head cap It is essential that the traction on the wire be directed vertically upward (Fig 230) The wire should be attached to the arch bar in the region of the first molar tooth and the frontal insert in the head cap should be placed to assure the vertical direction of

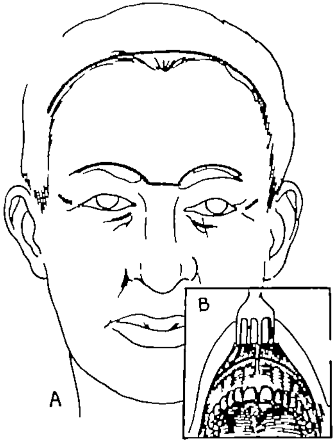

Fig 229 A Various cutaneous incisions for direct interosseous wiring B. Transverse vestibular incision to expose the skeletal framework (after Huffman, 1957)

the wire This type of fixation may be indicated in certain multiple fractures of the facial bones but cannot be employed when a headcap is contraindicated in a patient with a head injury requiring craniotomy We have observed disfiguring scars as a result of cutting the skin by the wires when care is not taken to place the wires correctly A similar type of wire traction of a different type employed in comminuted fractures, is discussed later in this chapter

Fracture of the Edentulous Maxilla

Two plans of treatment are available if the maxilla is edentulous In backward displacement of the bone, not sufficiently extensive to affect the facial contour the Kingsley type of splint adapted to the patient s denture or to a specially constructed base plate provides upward pressure and is a ictory method

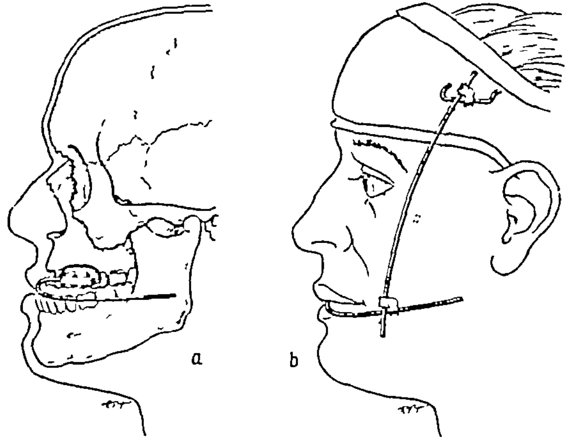

FIG. [illegible] Kirschner wire traction apparatus for reducing an impaction of the maxilla

A. Method of attaching lateral arm to splint.

B. By adjusting the curvature of the wire the required amount of force is exerted on the fragment. Intermaxillary elastic traction should also be used. After reduction the wires are straightened and they provide fixation of the fractured maxilla.

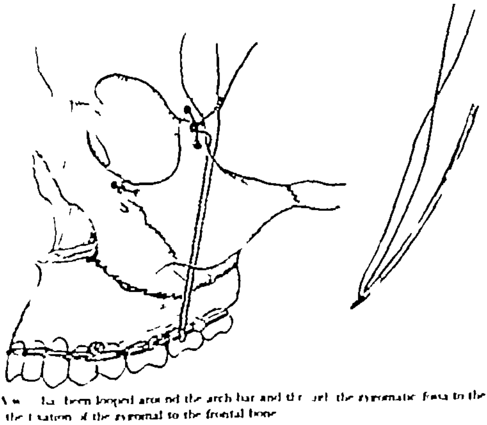

FIG. [illegible] A wire has been looped around the arch bar and th[illegible] [illegible] the zygomatic fossa to the interosseous wire a[illegible] [illegible] the fixation of the zygoma to the frontal bone.

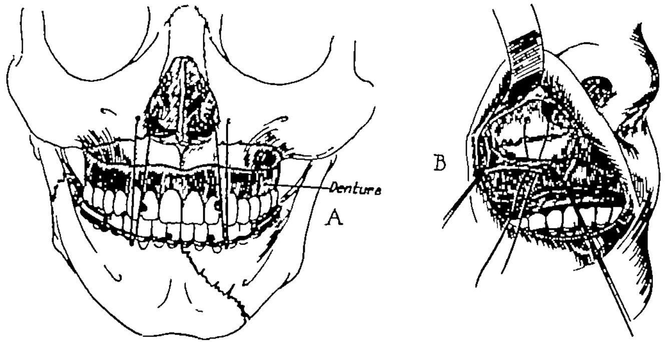

FIG 231 Guerin's fracture of the edentulous maxilla associated with fracture of the mandible

A. Fixation of the mandibular fragments is achieved by an arch bar appliance. The patient's denture is employed to establish the dental occlusion. Wires looped around the mandibular arch bar and through drill holes in the lateral borders of the pyriform aperture assure fixation.

B. Intraoral exposure of the pyriform aperture.

If the patient's denture is available, it can be employed for fixation Figure 231 illustrates a case of Guerin's fracture in an edentulous maxilla with a concomitant mandibular fracture. Stainless steel wire is looped around the mandibular arch and then fastened to the edge of the pyriform aperture. If the displacement is extensive and associated with radiating fractures of the hard palate, holes may be drilled through the anterior section of the alveolar process. Wires passed through these holes and out through the oral cavity are used to achieve forward traction and are attached to a cranial fixation apparatus (Fig 232, 233)

Comminuted Fractures of the Maxilla

In severe crash injuries, multiple fractures of the maxilla with comminution are often associated with fractures of other bones of the middle portion of the face (Fig 234) In comminuted fractures, in addition to the intra-oral appliances outlined above, direct interosseous wiring can be employed to bring the separated fragments together This procedure is especially suitable in severe injuries where the external wound permits visualization of the fragments.

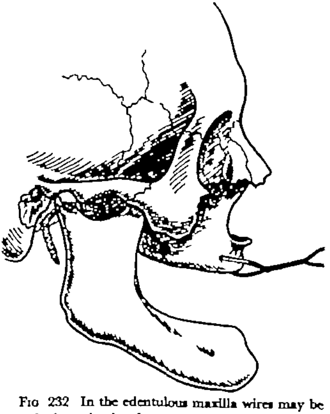

FIG 232 In the edentulous maxilla wires may be passed through the fragment and attached to a cranial fixation appliance.

In closed comminuted fractures, ex

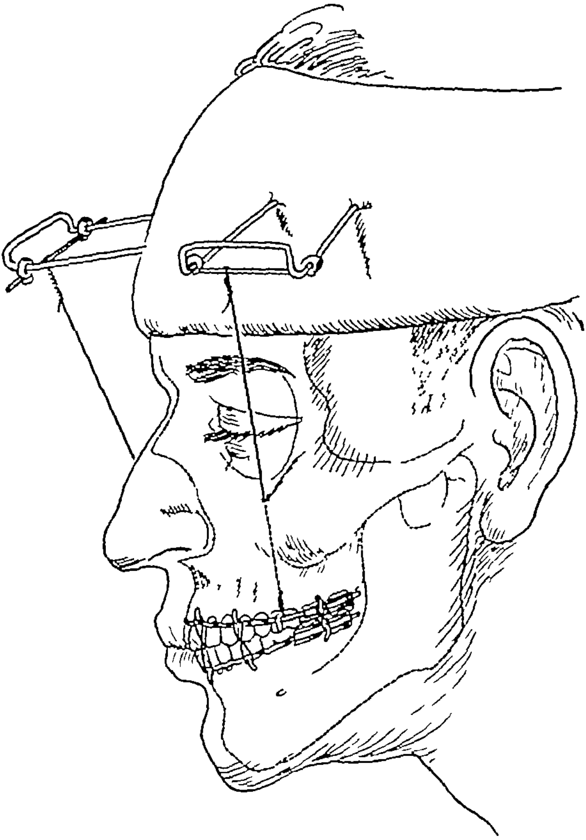

FIG. 30. *Transcutaneous traction wire for cranial fixation of the fractured maxilla (Lederspiel 1930)*

formed into a button-shaped knot. Continuous traction is effected by elastic bands which extend from the wire button to a vertical bar attached to a headcap the wires are retained for one week and are then removed (See Figs 303 304 Chapter 11)

Because comminuted fractures involving the palate and alveolar processes are difficult to assemble, especially when there are no teeth available for fixation one is justified in assembling the parts with wire sutures when necessary This should be accomplished while the fragments are loose and can be easily manipulated. Supplementary procedures with intra-oral fixation appliances may also be indicated to obtain effective immobilization.

A special problem is encountered in maxillary fractures with comminution The displacement of the tooth bearing segment of the maxilla is reduced but comminuted fragments around the pyriform aperture remain retroposed. The intra-oral approach permits direct observation of the condition. The fragments may be pushed forward with an elevator placed up and behind the frontal process of the maxilla through the nasal cavity or through the canine fosa into the maxillary sinus packing the maxillary sinus may be required to maintain the position of comminuted fragments.

Compound Fractures and Gunshot Wounds of the Maxilla

Gunshot fractures of the maxilla are characterized by comminution and destruction of bone, laceration of soft tissues of the face and loss of teeth. The bony articulations of the maxilla tend to prevent complete detachment of the bone. Because the denser portions resist the force of a projectile the fracture may be transmitted to the nasal and zygomatic bones, or to the base of the skull

The principles of immobilization of gunshot fractures of the maxilla do not differ materially from similar injuries resulting

FIG 234 Appearance of patient with multiple fractures of the maxilla and mandible sustained in an automobile accident.

from other causes modifications in the type of treatment however are necessary to overcome peculiarities associated with such wounds. The teeth, bony structures, and soft tissues within the vicinity of the maxilla are usually damaged Intra-oral fixation appliances must be used to cope with these conditions. If loss of teeth or bone is not appreciable simple immobilization may be attained by the methods outlined earlier in this chapter not infrequently however destruction of the teeth as well as surrounding soft tissues is so extensive that appliances must be designed not only to immobilize the existing fragments of bone, but also to close defects of the palate and to support the soft tissues Such appliances are indispensable for successful plastic repair at a later date, and are exemplified by the case shown in Figure 235

Bone fragments exposed in gunshot wounds, can be immobilized by direct wiring The case shown in Figure 236 is characterized by marked destruction of soft tissues and comminution of the upper jaw Holes were drilled through the exposed

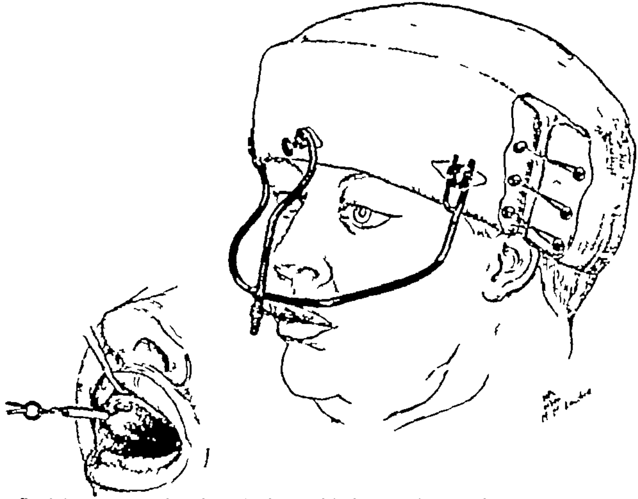

FIG 233 Edentulous patient with marked backward displacement of the upper jaw Stainless steel wires are passed through the anterior alveolar processes to form a loop elastic bands extend from the loop to external bar to draw the jaw forward. The rubber tube extending from the oral cavity prevents ulceration of the lips

posure for interosseous wiring can be obtained by suitably placed external incisions at the fronto-zygomatic junction in the skin of the lower eyelid and above the rim of the floor of the orbit (Fig 229)

Good exposure can also be obtained by the intra-oral vestibular approach (see Fig 281 Chapter 9) An incision is made on the labial aspect of the upper oral vestibule A flap of oral mucosa is dissected from the orbicularis oris muscle until the depth of the sulcus is reached The periosteum is incised at this point and raised over the anterior surface of the maxilla exposing the latter and respecting the infra-orbital nerves and vessels which remain attached to the soft tissues. The anterior surface of the maxilla can be exposed as far upward as the inferior orbital border by subperiosteal retraction of the soft tissues of the face The anterior surface of the zygoma can also be exposed The fracture lines can be seen and the degree of displacement of the fragment may be observed under direct observation with good illumination

Backward displacement of comminuted fragments in the infra-orbital region and in the region of the pyriform aperture unless corrected may result in severe deformity The area is exposed through the intra-oral route to correct the condition one or more holes are drilled through the infra-orbital rim and stainless steel wire is passed through the holes The wire ends are brought out through the skin just below the infra-orbital margin extending outward about one inch and are twisted together above the level of the skin and

formed into a button-shaped knot. *Continuous traction* is effected by elastic bands which extend from the wire button to a vertical bar attached to a headcap the wires are retained for one week and are then removed (See Figs. 303 304 Chapter 11)

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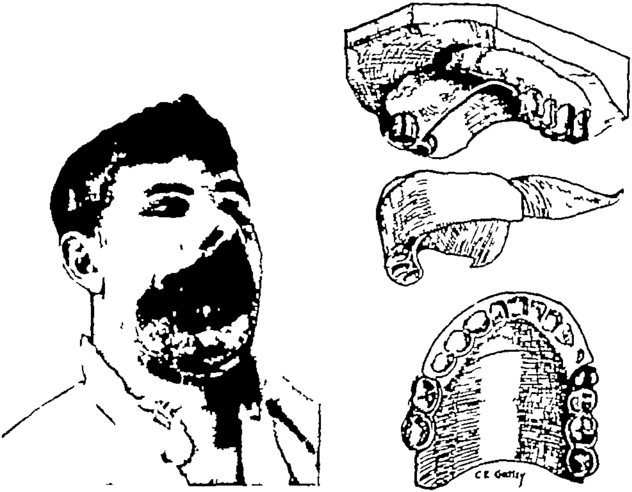

Fig. 213. (*Left*) This patient suffered comminuted fracture of the maxilla with destruction of the anterior portion and vertical fracture of the right side of the maxilla and in addition loss of the median section of the upper lip.

(*Right*) The cast of the upper jaw of the same patient shows immobilization of the fracture by a band and wire splint cemented to the teeth. A base-plate is retained by attachment to the wire of the splint, and has sufficient fullness and contour to prevent undesirable adhesions and contraction of the soft tissues. It also serves later as a supporting appliance.

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COMPLICATIONS IN MAXILLARY FRACTURES

Early Complications

Early complications following fractures of the maxilla include primary hemorrhage, respiratory complications and complications due to infection such as secondary hemorrhage, osteitis and osteomyelitis. Fractures of the maxilla may be associated with fractures of the bones of the fronto-ethmoidal region (see Chapter 10).

Primary Hemorrhage

Primary hemorrhage from fracture of the maxilla is fairly common. Bleeding usually originates in the nasal cavity or nasopharynx, for most maxillary fractures involve the nasal cavities and the maxillary sinuses. Unless the descending palatine and sphenopalatine arteries are injured, bleeding usually ceases spontaneously. Hemorrhage, however, may be abundant and may require nasal packing and even the placing

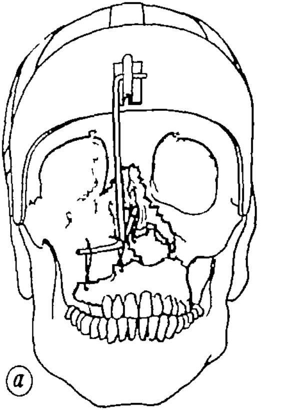


FIG. 236. Immobilization of maxillary fragment following compound fracture. Owing to the free exposure of the superior aspect of the maxilla this method of direct wiring from the bone to an extension from the head-gear is efficient in some cases. (*Left*) Technique of suspension.
(*Right*) Photograph of patient having suffered gunshot wound showing appliance illustrated on left.

of a postnasal pack before control of the bleeding is achieved.

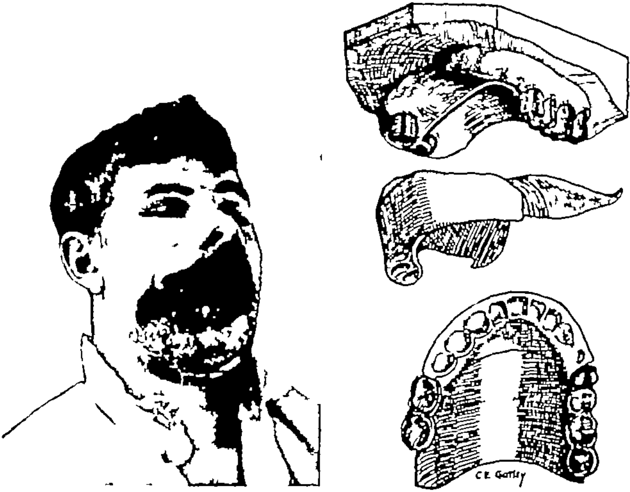
Respiratory Complications

Respiratory complications in maxillary fractures occur more frequently than in fractures of the mandible because of nasal involvement. When marked backward displacement of the maxilla has occurred there may be considerable edema involving not only the soft palate but extending into the pharynx this condition associated with nasal lesions, may cause marked nasopharyngeal obstruction. Patients who have had the jaws wired together may require release of intermaxillary fixation and the reemployment of fixation using a headcap to permit free movements of the mandible. A tube lubricated with 2 per cent procaine ointment through one or each buccal sulcus and retained for 48 hours usually allows a satisfactory air inflow without the need for tracheotomy. Because of an inadequate airway these patients tend to develop atelectasis due to the plugging of the bronchi Deep breathing exercises should be encouraged and adequate antibiotic therapy should be instituted to prevent pneumonia.

Infection

Infection in the line of fracture may be due to faulty immobilization of fragments, the presence of foreign bodies in the wound teeth in the line of fracture and associated soft tissue wounds. These causes of infection are discussed in the chapter dealing with fractures of the mandible similar principles of treatment apply to the fractured maxilla

The maxillary sinuses usually become filled with blood when bones of the middle third of the face are fractured because of injury to the mucous membrane which lines the sinuses. A flare up of infection may



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Primary hemorrhage from fracture of the maxilla is fairly common Bleeding usually originates in the nasal cavity or nasopharynx for most maxillary fractures involve the nasal cavities and the maxillary sinuses. Unless the descending palatine and sphenopalatine arteries are injured bleeding usually ceases spontaneously Hemorrhage however may be abundant and may require nasal packing and even the placing

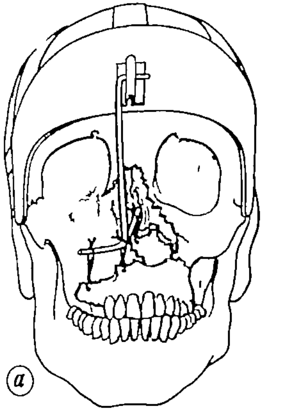

FIG. 236. Immobilization of maxillary fragment following compound fracture. Owing to the free exposure of the superior aspect of the maxilla this method of direct wiring from the bone to an extension from the head-gear is efficient in some cases. (*Left*) Technique of suspension.
(*Right*) Photograph of patient having suffered gunshot wound showing appliance illustrated on left.

of a postnasal pack before control of the bleeding is achieved.

Respiratory Complications

Respiratory complications in maxillary fractures occur more frequently than in fractures of the mandible because of nasal involvement. When marked backward displacement of the maxilla has occurred there may be considerable edema, involving not only the soft palate but extending into the pharynx this condition associated with nasal lesions, may cause marked nasopharyngeal obstruction Patients who have had the jaws wired together may require release of intermaxillary fixation and the re employment of fixation using a headcap to permit free movements of the mandible A tube lubricated with 2 per cent procaine ointment through one or each buccal sulcus and retained for 48 hours usually allows a satisfactory air inflow without the need for tracheotomy Because of an inadequate airway these patients tend to develop atelectasis due to the plugging of the bronchi Deep breathing exercises should be encouraged and adequate antibiotic therapy should be instituted to prevent pneumonia.

Infection

Infection in the line of fracture may be due to faulty immobilization of fragments the presence of foreign bodies in the wound teeth in the line of fracture and associated soft tissue wounds. These causes of infection are discussed in the chapter dealing with fractures of the mandible similar principles of treatment apply to the fractured maxilla

The maxillary sinuses usually become filled with blood when bones of the middle third of the face are fractured because of injury to the mucous membrane which lines the sinuses. A flare-up of infection may

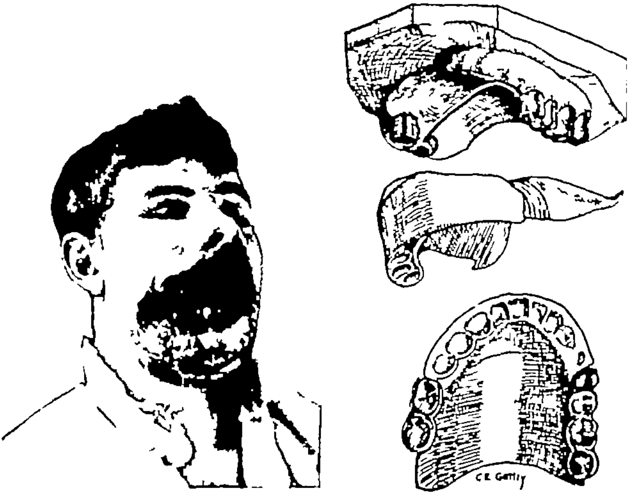

Fig 235 (*Left*) This patient suffered comminuted fracture of the maxilla with destruction of the anterior portion, and vertical fracture of the right side of the maxilla and in addition, loss of the median section of the upper lip

(*Right*) The cast of the upper jaw of the same patient shows immobilization of the fracture by a band and wire splint cemented to the teeth. A base-plate is retained by attachment to the wire of the splint and has sufficient fullness and contour to prevent undesirable adhesion and contraction of the soft tissues It also serves later as a supporting appliance

ends of the bone in this case wires were passed through the holes and the fragments were suspended to an external bar fastened to a headcap

COMPLICATIONS IN MAXILLARY FRACTURES

Early Complications

Early complications following fractures of the maxilla include primary hemorrhage respiratory complications and complications due to infection such as secondary hemorrhage osteitis and osteomyelitis Fractures of the maxilla may be associated with fractures of the bones of the fronto-ethmoidal region (see Chapter 10)

Primary Hemorrhage

Primary hemorrhage from fracture of the maxilla is fairly common Bleeding usually originates in the nasal cavity or nasopharynx for most maxillary fractures involve the nasal cavities and the maxillary sinuses. Unless the descending palatine and sphenopalatine arteries are injured bleeding usually ceases spontaneously Hemorrhage however may be abundant and may require nasal packing and even the placer

lar to those occurring in mandibular fractures do not occur as frequently

High fractures of the maxilla and of the bones of the middle third of the face may involve the bones of the fronto-ethmoidal region resulting in lesions of the anterior cranial fossa. The management of these complications is discussed elsewhere in the text (see Chapter 10)

Fractures of the maxilla are frequently associated with fractures of the zygoma these may affect the floor of the orbit. The management of such conditions is discussed in the chapter dealing with fractures of the zygoma (see Chapter 9)

Late Complications

Late complications of maxillary fractures include delayed union non union malunion infra-orbital anesthesia and interference with lacrimal function

Delayed Union

Healing of maxillary fractures is rapid delayed union is unusual but can occur in cases where inadequate cranial fixation has been provided. We have observed a number of cases in which temporary removable fixation appliances were improperly employed by patients who frequently removed the apparatus for a period of time, permitting motion of the maxilla particularly during mastication Delayed union has also been observed in cases of infection and suppuration Adequate immobilization usually permits consolidation of the fracture.

Delayed Reduction of Maxillary Fractures

Because consolidation is rapid the delayed reduction of maxillary fractures may present difficulties particularly in the impacted variety Even after two weeks, considerable difficulty may be encountered in reducing the displaced maxilla by simple intermaxillary elastic traction. The line of fracture can be exposed through the oral vestibular approach when early consolidation occurs. Using a narrow fine-tipped osteotome the osteotomy is done through the fracture line, thus releasing the fractured segment from its displaced position (Fig 237) This type of open reduction is preferable to methods that have been used and described in the literature employing skeletal traction with weights similar to orthopedic methods for reducing overriding infractures of the long bones. The method consists of suspending a weight on a pulley that is maintained by a Balkan frame These methods are uncomfortable and painful for the patient who must remain immobilized in bed and are frequently unsuccessful

Non union

Non union of maxillary fractures is a rare condition We have observed only one such case still non united after a period of six months which required open reduction and bone grafting Such non-union indicates failure to provide even the most elementary type of maxillary fixation

Malunion

Malunion is the result of inadequate diagnosis, immobilization and alignment of the fragments. Malunion with gross posterior as well as lateral displacement of the maxilla affects mastication and may result in severe deformity Such displacement is characterized by retrusion of the middle portion of the face and pseudoprognathism an apparent protrusion of the lower jaw flatness of the zygomatic processes a change in the outline of the palpebral fissures and depression of the nasal bridge.

The surgical treatment of malunited fractures of the maxilla is described elsewhere in this text (see Chapter 24)

Interference with the Function of the Lacrimal Apparatus

The nasolacrimal apparatus may be affected in maxillary fractures at the level of the lacrimal sac, due to backward dis-

occur in the form of an acute purulent maxillary sinusitis in patients who have had chronic sinusitis before the accident. Administration of antibiotics and irrigations of the maxillary sinus after puncturing the wall of the inferior meatus, or by passing a small sound through the ostium in the middle meatus assures the surgical drainage of the infected sinus.

Exploration of the maxillary sinus through a surgical opening in the canine fossa is indicated when a fragment of bone or a tooth is forced into the sinus. Suppuration is frequently due to the presence of a foreign body and can be remedied only after its removal. Following surgical exploration of the maxillary sinus, the canine fossa opening is permitted to close and drainage is assured by establishing a window in the anterior portion of the lateral wall of the inferior meatus.

Complications due to infection in maxillary fractures such as secondary hemorrhage, osteitis and osteomyelitis, while simi

Fig. 17. Malunited fracture of the maxilla due to an [illegible] injury.

A. Note backward displacement of the maxillary portion of the face and characteristic deepening of the nasolabial fold.

B. After osteotomy and reduction; fixation by intraoral [illegible] bar appliances and intermaxillary wiring and cranial fixation by elastic traction headgear.

C. Improvement in contour obtained after osteotomy and reduction.

D. Disturbance of the dental occlusion. The maxillary teeth are [illegible] the mandibular teeth and there is an open-bite [illegible] malocclusion is due to the backward and upward tilt of the impacted maxilla.

E. [illegible] dental occlusal relationships reestablished after osteotomy.

8

FRACTURES OF THE BONES AND CARTILAGES OF THE NOSE

ANATOMICAL CONSIDERATIONS

Covering Tissues of the Nose

The skin of the nose is tightly bound to the alar cartilages The skin and musculature are loosely attached and mobile over the lateral cartilages and nasal bones. The skin is thick and rich in sebaceous glands over the lower portion of the nose The arteries and veins of the nose are superficial in the soft tissues the plane of dissection in nasal operations should therefore be close to the osteocartilaginous framework to avoid injury of these vessels and unnecessary bleeding

Bony Framework of the Nose

The osseous nose is formed by the paired nasal bones these are joined in the mid line and are supported posteriorly by the nasal spine of the frontal bone and laterally by the frontal processes of the maxilla. The osseous lateral walls of the nose are formed by the nasal bones and frontal processes of the maxilla (Fig 239)

The nasal bones are quadrangular thick and narrow above, and thin and wide below (Fig 240) their anterior surfaces are concave from above downward in the upper portion convex in the lower and also convex from side to side. Fractures of the nasal bones rarely involve the strongly reinforced upper portion for the nasal spine of the frontal bone lends support to this part of the bony bridge. The frontal process of the maxilla is a plate of bone which projects upward and medially from the body of the maxilla, forming the lateral boundary of the lateral nasal wall The posterolateral border of the frontal process of the maxilla with the neighboring groove on the lacrimal bone constitutes the lacrimal fossa

Cartilaginous Structures of the Nose

The cartilages of the nose are subjected to movements by the nasal musculature and play an important role in nasal physiology Their function is inhibited in facial paralysis the cartilages of the nose are immobile due to paralysis of the musculature and an inadequate nasal airway is noted on the paralyzed side (Fig 241)

The nose is not a static structure to be shaped at will in plastic surgical operations avoidance of injury to the nasal musculature and the preservation of the dynamics of the nasal cartilages is an important consideration in nasal surgery

The cartilaginous external nose is situated anterior to the pyriform aperture The aperture is bounded laterally by sharp margins and is limited above by the lower borders of the nasal bones and the frontal processes of the maxilla The margins are thickened below and curve medially toward the anterior nasal spine of the maxilla.

The septal cartilage is a quadrangular shaped lamina which forms the framework of the anterior inferior portion of the sep-

placement of the frontal process of the maxilla in fractures associated with comminuted fractures of the nasal bones. The lacrimal duct may also be affected and may be severed, kinked or obstructed by a bone fragment. Secretion accumulates within the sac in such cases, gradual dilation of the sac producing a swelling at the side of the nose. Digital pressure causes an emission of opalescent, stringy and sometimes purulent fluid through the punctum. Suppuration from the punctum usually results in conjunctival irritation and mechanical obstruction of vision due to the presence of fluid on the eyeball. Treatment consists of establishing a new channel into the nose by employing a method such as the Toti-Mosher operation (see Chapter 21).

Infra-orbital Anesthesia

Infra-orbital nerve function may be temporarily interrupted as a result of injury, compression or severance. Even after section, spontaneous repair of the nerve restores sensation to the upper lip. The cases of permanent anesthesia of the upper lip observed by us appear to be the result of unrelieved compression of the nerve within the infra-orbital canal.

Deformity

Because of associated fractures of other bones in the middle third of the face, treatment necessitates not only replacement of the tooth-bearing segment of the maxilla in adequate occlusion but also reduction of nasal fractures and straightening of the deformed nasal septum to assure a clear airway. Depression of the zygoma requires correction to bring the eye on the affected side to its original level, reduce the possibility of permanent diplopia and permit free movement of the coronoid process of the mandible. The ultimate appearance of the patient depends upon adequate replacement of the bones in order to avoid the typical dish-face appearance resulting from a retroposed maxilla, flattened nose and widened intercanthal distance (Fig. 238).

Fig. 238. Malunited fracture of the maxilla.

A, Deformity produced by malunited fracture of maxilla caused by automobile crash injury. Note extraocular muscle disturbance due to involvement of the orbital cavity.

B, Backward depression of the middle third of the face due to malunited maxillary fracture.

C, Backward displacement of the maxillary dentition due to malunited fracture.

8

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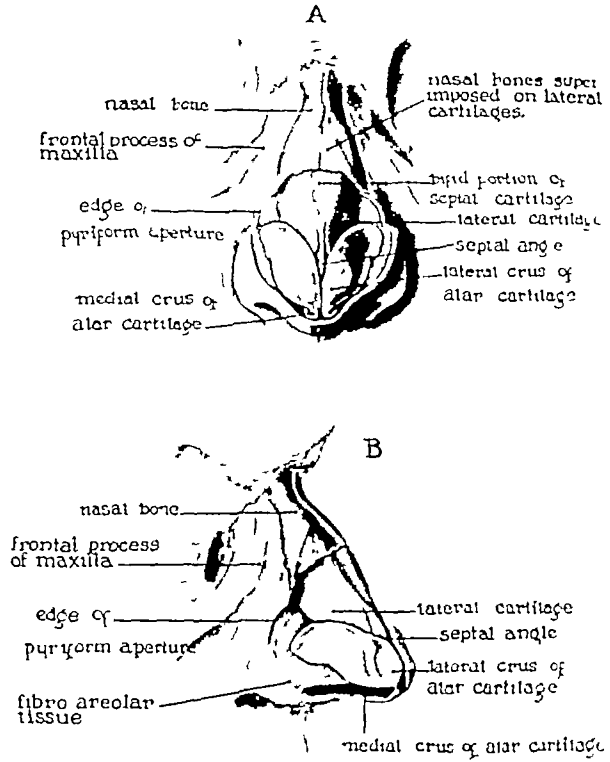

Fig. 239. Anatomy of the nasal framework.

A. Anterior view.
B. Lateral view.

Figs. 239 to 244 from J. M. Converse, Ann. Otol. Rhin. & Laryng. [illegible]

tum, it protrudes in front of the pyriform aperture. The anterosuperior angle of the septal cartilage, an important surgical landmark, is designated as the septal angle (Figs. 239, 241); this angle is located immediately above the alar cartilages in an area referred to as the supratip area. The major portion of the septal cartilage is

firmly bound to the vomer the perichondrium of the cartilage being continuous with the periosteum of the vomer The lower part of the septal cartilage extends over the smooth surface of the nasal spine the septal cartilage is mobile in this area side to side movements are possible because of the flexible relations of the cartilage and the bony surface The perichondrium of the septal cartilage extends outward to join with the periosteum of the wider nasal spine thus simulating a joint capsule within which lateral movements of the septal cartilage are possible The plasticity of this portion of the septum known as the mobile septum increases the flexibility of the septal cartilage. The free margin of the septal cartilage is separated from the columella by the juxtaposition of two mucocutaneous flaps in an area known as the membranous septum The layers of the membranous septum extend forward diverging to join with the cutaneous covering of the medial crura which form the cartilaginous support of the columella.

The lateral cartilages are paired structures attached to the medial portion of the frontal process of the maxilla and the nasal bones above, and to the septal cartilage in the midline The lateral cartilages are connected below to the alar cartilages by means of dense connective tissue, the upper edge of the alar cartilage overlapping the lower aspect of the lateral cartilage. The outer margin of the lateral cartilage is separated from the edge of the pyriform aperture by fibroareolar tissue.

Relationship of the Lateral Cartilages to the Nasal Bones

The relationship of the lateral cartilages to the nasal bones is established during the embryological development of these structures. The nasal bones develop from membrane on the surface of the cartilaginous nasal capsule, thus accounting for the upward extension of the lateral cartilage on the inner surface of the nasal bone. The

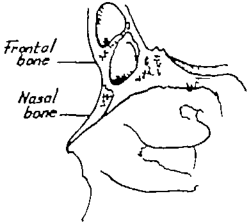

FIG 240 Sagittal section of the nasal bones illustrating thick upper portion resting on the nasal spine of the frontal bone and the thinner lower portion.

FIG 241 Illustrating the immobility of the nasal cartilages when the nasal muscles are paralyzed.

A. The nose during inspiration. Note the opening of the naris on the unaffected left side. On the right, due to paralysis immobility of the naris results in obstruction of the nasal airway

B Appearance of the nares during expiration.

overriding of the lateral cartilage and nasal bone may extend 2 cm. (Fig 242) The fusion of the perichondrium and the periosteum forms an intimate relationship between the cartilage and bone. The extent of this anatomical neighborliness may be observed when dissecting the nose. The upper limit of the lateral cartilage is exposed when the overlying nasal bone is removed. This relationship is of clinical significance in fractures, for the lateral cartilage participates in displacement of the bone and is rarely detached from it

Relationship of the Lateral Cartilages to the Septum

The septal cartilage extends upward beneath the nasal bones for a distance equal

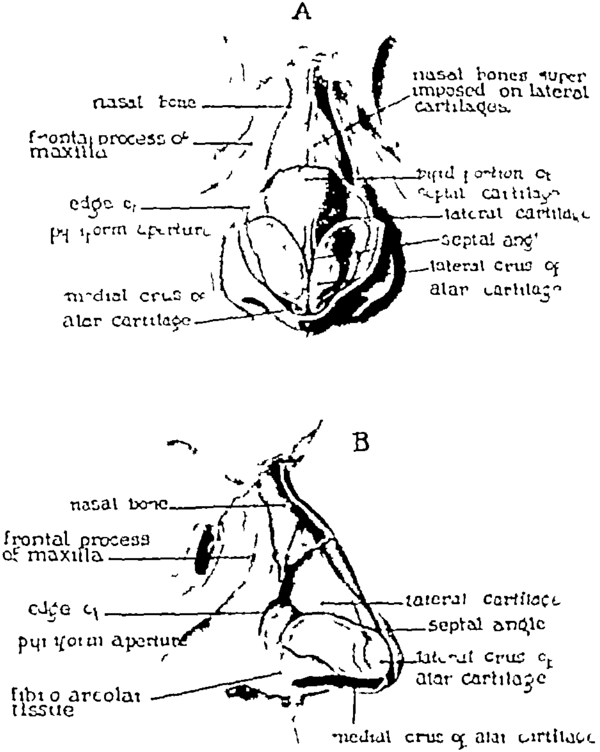

Fig. 239. Anatomy of the nasal framework.

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(Fig. [illegible] from J. M. Converse: Ann. Otol. Rhin. & Laryng. [illegible])

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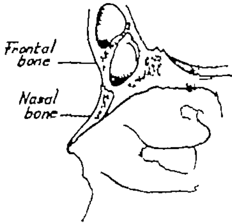

FIG 240 Sagittal section of the nasal bones illustrating thick upper portion resting on the nasal spine of the frontal bone and the thinner lower portion

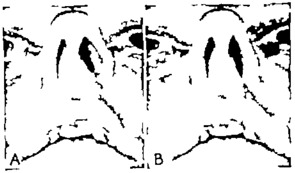

FIG 241 Illustrating the immobility of the nasal cartilages when the nasal muscles are paralyzed.

A. The nose during inspiration. Note the opening of the naris on the unaffected left side. On the right, due to paralysis, immobility of the naris results in obstruction of the nasal airway

B. Appearance of the nares during expiration.

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Relationship of the Lateral Cartilages to the Septum

The septal cartilage extends upward beneath the nasal bones for a distance equal

to that of the lateral cartilages. The septal cartilage terminates in a sharp edge in the region of the septal angle and the adjacent portion of the dorsal border The cartilage is thicker near its junction with the perpendicular plate of the ethmoid the increased thickness extends to the dorsal border of the cartilage in this area The dorsal border of the cartilaginous nasal septum undergoes alteration in width and configuration toward the nasal bones bifurcating into a Y resulting in a supraseptal groove between the limbs of the Y (Fig 212) The groove is readily seen and palpated in some individuals, but it is usually not distinguishable on the surface being masked by the perichondrium thick connective tissue aponeurosis of the nasalis muscle and subcutaneous tissue The supraseptal groove is wide near the junction with the nasal bones and narrower toward the septal angle

The nasal hump often a prominent portion of the dorsum is formed above by the nasal bones and below by the widened portion of the septal cartilage and by the lateral cartilages. The dorsal hump is fusiform narrow above wide near the junction of the lateral cartilages and nasal bones, and narrow above the septal angle

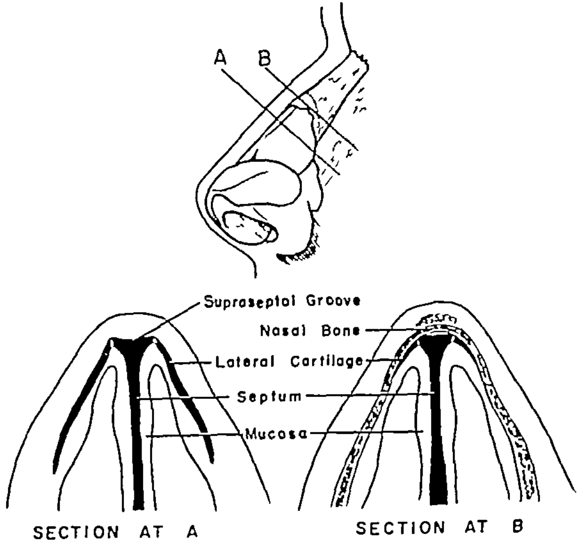


Fig. 214 Diagrams made from serial sections of the external nose through a frontal plane The upper drawing illustrates the levels A and B at which cross-sections have been made Sectional view A demonstrates the relationship of lateral and septal cartilages Sectional view B shows the relationship of lateral and septal cartilages with the nasal bones

The lateral and septal cartilages do not overlap but join end to end The structures are intimately connected near the nasal bones. Although there is an appearance of cartilaginous continuity histological examination always reveals a separation between the ends continuity of the perichondrium is frequently observed Dense connective tissue binds the cartilaginous ends. The septal and lateral cartilages are separated by a narrow cleft which becomes obvious toward the septal angle Fibro-areolar tissue in this area permits inward and outward movement of the lateral cartilages.

The Alar Cartilages

The alar cartilages are paired structures which form the cartilaginous framework of the tip of the nose (Fig 239) Each cartilage consists of two portions a medial crus and a lateral crus, which are joined at the highest point of the tip of the nose this prominent point locates the dome of the alar cartilage. The medial crura after their junction curve medially and downward to the columella and are rotated the upper surface becoming medial They diverge as they extend downward, the maximum divergence being reached at the widened base of the columella Although the size and shape of the alar cartilages vary the lateral crus usually occupies little more than the medial half of the ala The remaining portion of the ala is supported by the characteristic fibroareolar tissue of the nose. The border of the nostril is supported by dense collagenous tissue arranged in resilient longitudinal bundles

The alar cartilage is intimately joined to the skin in the columella the medial crus being dissected from the skin with difficulty The lateral crus approximates the free margin of the external naris border in its medial third, and extends away from its lateral portion An incision along the free margin of the cartilage should allow for this conformation and extend farther away from the nostril border in its lateral portion. The incision should follow the curve of the free margin of the cartilage when dividing it into upper and lower segments to avoid excising all of the lateral portion of the cartilage

The dome point of union of lateral and medial crura is separated from the margin of the nostril by a triangular-shaped area known as the soft triangle (Fig 243) this consists of two juxtaposed layers of the skin the covering skin of the nose and the lining vestibular skin separated by loose areolar tissue An incision close to the nostril border should be avoided. When exposing the dome the free margin of the alar cartilage should be followed thus avoiding incision through the soft triangle and preventing postoperative notching of the nostril border

The lateral crura of the alar cartilages diverge in the supratip area leaving a triangular-shaped area between them into which the septal angle is fitted. Because the dorsum in this area is supported only by the septal angle it is referred to as the weak triangle (Fig 244) The lateral and alar cartilages are connected by aponeurotic like tissue which maintains the at

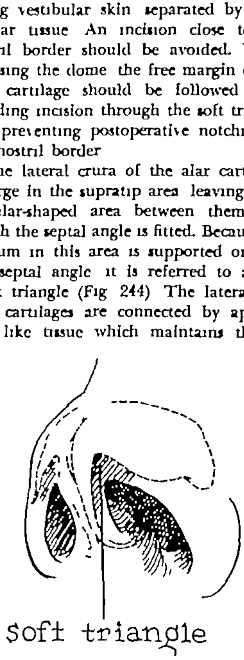


FIG. 243 The soft triangle of the nose. A triangular-shaped area consisting of two juxtaposed layers of skin separates the dome of the alar cartilage from the nostril border The soft triangle is represented by the shaded area.

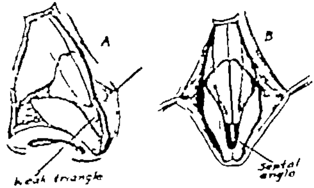


FIG. 244 The weak triangle of the nose A. Dissection showing nasal structures. The overlying soft structures have been removed. The aponeurosis covers the triangle between the alar and lateral cartilages over the septal angle B. Septal angle exposed after removal of the aponeurosis. (J M Converse Arch. Otolaryng 52 671 1950)

tachment of the alar cartilages to the septal angle thus acting as a suspensory ligament to the tip of the nose which droops when the support of the septal angle is lost by injury or operative removal this deformity may be accompanied by retraction of the columella which is also due to loss of septal support.

The Columella

The columella extends from the tip of the nose to the lip joining the latter at the upper portion of the philtrum and separating the external nares. The posterior portion of the columella is wider than the anterior portion due to the divergence of the medial crura of the alar cartilages the lower ends of which embrace the lower margin of the septal cartilage. The contour of the columella depends upon the shape and the degree of flare of the medial crura of the alar cartilages the widening at the base of the columella is due to the outward flare of the lower ends of the medial crura

The Vestibule

The vestibule extends anteriorly to the floor of the nose The crest which delimits the lower portion of the pyriform aperture can be palpated The lower border of the lateral cartilage protrudes into the vestibule forming a fold the limen nasi or internal naris (Fig 215) this fold is prolonged downward and medially along the crest of the pyriform aperture Inspired air is filtered warmed and moistened in the vestibule The valve-like action of the internal naris, through variations in position of the lateral cartilage in relation to the septum aids in controlling the currents of air which enter the nose.

Nasal ventilation is dependent upon the action of the lateral and alar cartilages, the contraction of the nasal musculature and passive movements due to variations of intranasal pressure. Malfunction of the external nose may result from injury or from faulty surgical procedures such as destruction of a part of the nasal musculature in an effort to thin the nasal structures, excessive removal of cartilage and consequently of the framework upon which the nasal musculature acts too wide resection of cartilage and vestibular lining which restricts the opening of the internal naris, operative procedures producing rigidity in the mobile and membranous septum and columella by overshortening the septal cartilage and excision of the membranous septum or injudicious implantation of cartilage between the layers of the membranous septum. It is essential to preserve the function of the depressor septi nasi muscle (Fig 216) for this structure tenses the membranous septum at the initiation of nasal inspiration

The Nasal Septum

The nasal septum is a median structure which divides the nasal cavity into two lateral chambers (Fig 217) The septal framework is composed of bony constituents and a cartilaginous constituent the septal cartilage The four bony components of the osseous septum are the perpendicular plate of the ethmoid the vomer the medial or nasal crest of the maxilla and the medial or nasal crest of the palatine bone Because

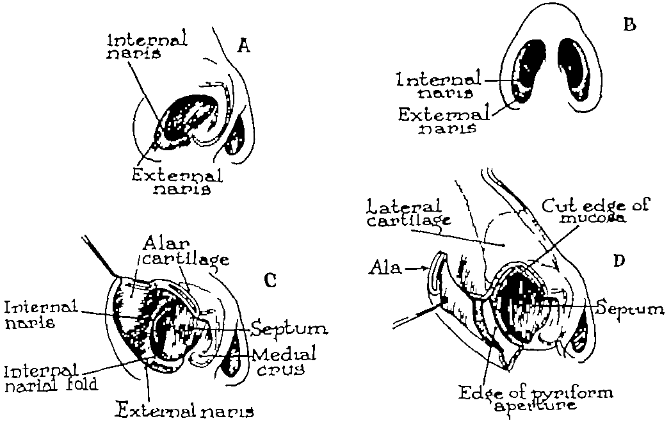


FIG 245 The internal naris

A and B. The external and internal nares, limits of the nasal vestibule.

C. The ala has been sectioned and retracted to show the internal naris, formed by the protruding lower border of the lateral cartilage, prolonged downward by the internal narial fold.

D The edge of the pyriform aperture is exposed demonstrating that the internal narial fold extends along the crest of the pyriform aperture.

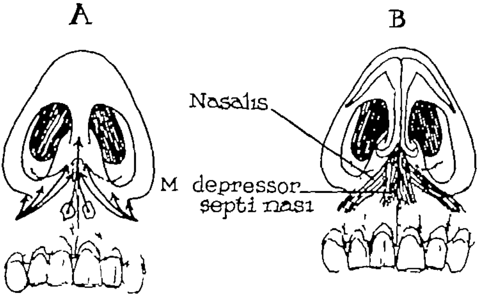


FIG 246. The depressor septi nasi muscle

A. Diagram showing the direction of the pull of the depressor septi nasi muscle.

B. Drawing representing the depressor septi nasi muscle joined by fibers from the nasalis penetrating through the base of the columella.

(Figs. 245 and 246 from J M. Converse, Ann. Otol. Rhin & Laryng 64 220 1955)

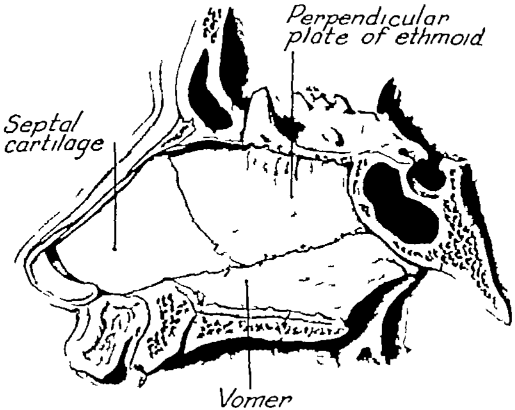


FIG 247 Bony and cartilaginous nasal septum

the septal framework is closely associated with the lateral cartilages and nasal bones, fracture of the septum is usually associated with fracture of the nasal bones.

The septal cartilage is held firmly in a groove formed by a divergence of the broad upper margins of the vomer a paired structure formed by the fusion of the two halves of the bone The cartilage is loosely attached in front of the vomer to the smooth upper surface of the nasal spine. The perichondrium diverges laterally on each side and is attached to the lateral border and the periosteum of the nasal spine forming a fibrous capsule around the joint The mobility of the lower portion of the septal cartilage permits side to side movements and acts as a shock absorbing mechanism which prevents frequent fracture of the septal framework the resiliency of the lateral and alar cartilages and of the septum accounts for the shock-absorbing role of these structures in preventing nasal fractures and also more severe craniofacial injuries.

SURGICAL PATHOLOGY

Fractures and dislocations vary with the site of impact and the direction of the striking force. The bony and cartilaginous portions of the nose may be affected simultaneously

Fractures and Dislocations of the Nasal Bones

A distinction is made between nasal fractures in children and those in adults. It will be recalled that the nasal bones in adults are intimately fused in the midline whereas in children each nasal bone may be fractured independently because they are not fused until adolescence Depressed fractures involving one nasal bone are uncommon in adults but occur frequently in children (Fig 248*A* *B*) Severe anteroposterior blows occasionally cause an open-book type of fracture in children (Fig 248*C*) Both nasal bones may be dislocated outward over the frontal processes of the maxilla or a posterior fracture-dislocation may occur the nasal bones being displaced

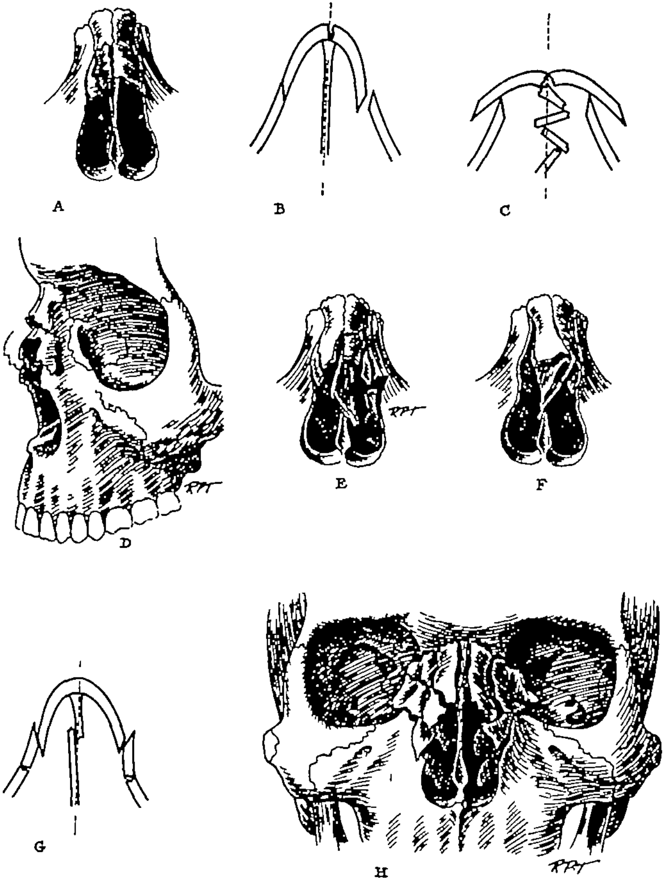


Fig 248. Various types of fractures of the nasal bones

A, B. Depressed fracture of one nasal bone.
C. Open-book type of fracture seen in children.
D Fracture of the nasal bones at the junction of the thick upper and thin lower portions.
E. Comminuted fracture.
F G Fracture-dislocation.
H Comminuted fracture of the nasal bones involving the frontal processes of the maxilla.

backward between the frontal processes of the maxilla Such fractures in children if neglected result in flattening of the nasal bridge Injuries to the nose in childhood are often unsuspected and may not be revealed until developmental changes accentuate the deformity

The nasal bones in adults usually remain attached to one another in the mid line when fractured An anteroposterior blow over the bridge of the nose may fracture the frail inferior edge of the bone (Fig 248*D* *E*). The nasofrontal articulation may be separated if the impact occurs at a higher level this however is an unusual occurrence. The base of the frontal process of the maxilla constitutes the boundary of the pyriform aperture. Fracture of the sharp margin of the pyriform aperture may cause it to protrude into the vestibule, thus obstructing the passage.

Most nasal fractures are due to blows which strike the nose from the side. In such cases both nasal bones are fractured at a horizontal level and dislocated to one side (Fig 248*F*) the septum is also fractured and the upper fragment of the septum is displaced laterally with the nasal bones. The level at which most of these fractures occurs is accounted for by the structure of the nasal bones, the thick upper part of the bones being more resistant than the lower thinner portion A survey of a series of one hundred and ninety nasal frac

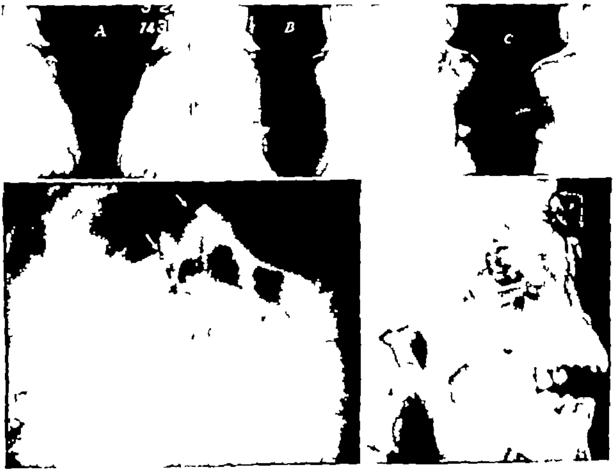


Fig 249. Roentgenograms showing various fractures of the nasal bones

A. Fracture at the tip

B Fracture at a higher level at the junction of the thick and thin portions of the nasal bones

C. The junction of the thick with the thin portion is at a higher level Fracture without displacement

D (lower left) Fracture involving right frontal process

E (lower right) Comminuted fracture

tures indicates that 80 per cent of the fractures occurred at the junction of the thick and thin portions of the nasal bones which varies in different individuals and appears to be a determining factor in the fracture level (Fig 249*A, B C*)

The frontal process of the maxilla unless subjected to unusual violence, remains intact in nasal fractures. A blow to the side of the nose may result in fracture of only one nasal bone (Fig 248*A, B*) it may injure the frontal process of the maxilla, causing depression of one side of the nose (Figs. 248*E* and 249*D*) or the entire bony arch may be dislocated from its attachment at the base and deviated to one side (Fig 248*F G*) A violent blow may cause comminution of the nasal bones and flattening of the entire arch (Figs. 248*H* and 249*E*)

The frontal processes of the maxilla are usually involved in severe nasal fractures. The nasal bones and frontal processes are pushed backward into the ethmoid in severe anteroposterior telescoping fractures. In fractures which also involve separation of the mid line suture, the nasal bones are pushed backward medially between the frontal processes, which are frequently fractured outward (Fig 248H) The most severe fractures are due to a direct anterior blow on the nasal bridge· these result in comminution and overlap of the fragments. Considerable comminution may also be noted in the lacrimal bones the lamina papyracea of the ethmoid, the walls of the ethmoid cells the cribriform plate and the orbital plate of the frontal bone. These comminuted fractures if neglected result in severe deformity Not only is the bridge of the nose flattened but the intercanthal distance is widened, and the medial wall of the orbit is displaced laterally (Fig 250*A*) The displaced fragments may penetrate the lacrimal sac, resulting in subsequent dacryocystitis and the interference with the evacuation of tears (Fig 250*B*) Such telescoping comminuted nasal fractures are often associated with the crash

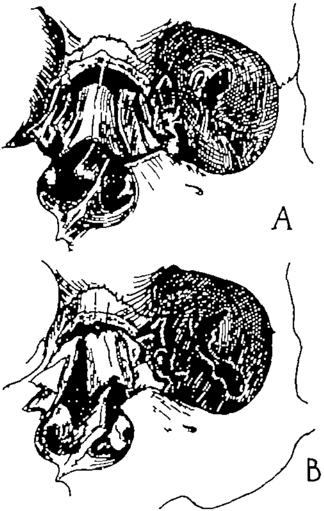


Fig 250 Comminuted fracture of the medial wall of the orbit. A. Backward displacement of the nasal bone and frontal process of the maxilla telescoped into the ethmoid and displacing the medial wall of the orbit laterally B. The bone fragments are displaced backward laterally to the medial wall of the orbit, penetrating the lacrimal sac (see Fig 265)

type multiple fracture of the middle third of the face which involves the fronto-ethmoidal region and the anterior cranial fossa (see Chapter 10)

Soft tissue wounds which expose the fractured nasal bones result in a compound fracture.

Fractures and Dislocations of the Septal Framework

Injury dislocation or fracture of the septal cartilage occurs commonly in nasal fractures. Dislocation of the septal cartilage may be associated with fractures of the nasal bones or may occur independently (Fig 251)

The septal cartilage bends and may be fractured or dislocated from the vomerine groove as a result of a side blow or of an "end-on" blow against the tip of the nose. As previously stated the lower portion of the septal cartilage is not attached in the vomerine groove and is capable of side-to-side movements the flexibility of the cartilage acts as a shock absorbing mechanism. When the degree of bending is exaggerated the cartilage is fractured along a vertical line at the junction between the lower mobile portion of the septal cartilage and the thicker main portion of the cartilage. The septal cartilage may also be fractured along a horizontal line parallel to the vomer groove in some cases the cartilage is dislocated out of the groove. A vertical fracture line may complicate the horizontal fracture the line of fracture usually occurring at the junction with the perpendicular plate of the ethmoid.

Fractures of the perpendicular plate of the ethmoid are a rule in fractures of the nasal bones, frequently occurring in conjunction with fracture-dislocation of the septal cartilage. Fractures of the vomer are unusual and probably occur only in a longitudinal fracture through the floor of the nose and palatine vault.

Due to the attachment of the fractured septal fragment to the fractured nasal bones, satisfactory re-alignment of the septum is often obtained by reducing the fractured nasal bones.

Dislocation of the septal cartilage from the vomerine groove and marked backward displacement may occur when the nose is struck by an "end-on" blow against the tip and the columella the septal cartilage *may be forced upward against the perpendicular plate of the ethmoid*. Such injuries are frequent in children. If the resulting displacement is sufficiently extensive shortening of the nose with upward displacement and deepened nasolabial folds may result in a severe deformity

The dislocation of the septal cartilage from the vomerine groove in children becomes manifest after the growth of the nose accentuates the deformity The free margin of the septal cartilage protrudes into one vestibule the columella is distorted and the nasal tip is widened due to the separation of the alar cartilages (Fig 252) Varying degrees of nasal obstruction occur in these cases.

A supratip depression along the dorsum of the nose is a frequent complication following fracture of the septal framework (Fig 253) It is due to a depression of the dorsal border of the septal cartilage or a downward displacement of the septal angle (the anterosuperior angle of the septal cartilage) these deformities are caused by overlapping of fractured cartilaginous fragments

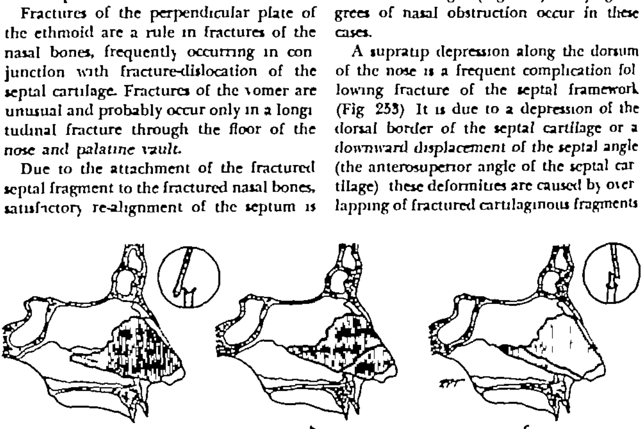


Fig 251 Fracture dislocations of the septal cartilage
A. Dislocation.
B Vertical fracture
C. Horizontal fracture

and contraction of torn mucoperichondrial septal flaps.

Some thickening of the lateral and alar cartilages may also be observed after nasal injuries this complication may be accounted for by subperichondrial hemorrhage and fibrosis.

EXAMINATION AND DIAGNOSIS

Clinical Examination

Nasal hemorrhage is usually of short duration and ceases spontaneously A deviation or a flattening of the nose may also be seen The swelling which occurs during the hours following the fracture is due to hematoma and edema and the deformity becomes obscured. Periorbital ecchymoses and swelling appear with subconjunctival hemorrhage which is usually bilateral. The patient experiences pain at the time of the accident and breathing through the nose is difficult because of intranasal hemorrhage blockage of the airway by blood clots edema of the mucous membrane swelling of the turbinates, and displacement of intranasal structures. Swelling may be marked and subcutaneous emphysema may be noted in patients who have attempted to clear the nasal airway by blowing the nose to remove blood clots air is blown through the torn mucoperiosteum of the fractured nasal bones into the subcutaneous space overlying and adjacent to the nose.

Palpation of the nasal bones reveals mobility and tenderness on slight pressure and crepitus, due to the presence of loose fragments of bone or to subcutaneous emphysema.

Following examination of the external nose, a complete intranasal examination is essential The nasal cavities are carefully cleansed of blood clots and the intranasal tissues are shrunk by the use of a vasoconstricting nasal spray Pledgets of cotton soaked in cocaine and adrenaline solution produce topical anesthesia Deviation of the septum is usually noted in fractures of the septal framework and ecchymosis and hematoma may be present at the site of fracture. A blunt-end silver probe assists in locating the site of the fracture line and the degree of displacement. The intranasal examination may be completely obstructed by a hematoma of the septum the mucoperichondrium on both sides being ballooned out by blood which fills the nasal airways on both sides.

Fig 252. Widening of the nasal tip as a result of fracture of the septum. A. Wide tip due to separation of alar cartilages produced by traction of the septal angle caused by pressure of the septal angle under right alar cartilage. B The deviation of the lower portion of the septal cartilage is exaggerated by pressure on the tip. Demonstrates the position of the septal angle under the right alar cartilage.

Fig 253 A. Depression of the dorsum and drooping of the tip resulting from fracture of the septal cartilage B Correction is obtained by septal cartilaginous implant and shortening of the lateral walls of the nose (see Chapter 22)

Roentgenographic Examination

Roentgenograms of the nasal bones are an important diagnostic measure, for they may reveal a linear fracture without displacement or with only slight displacement

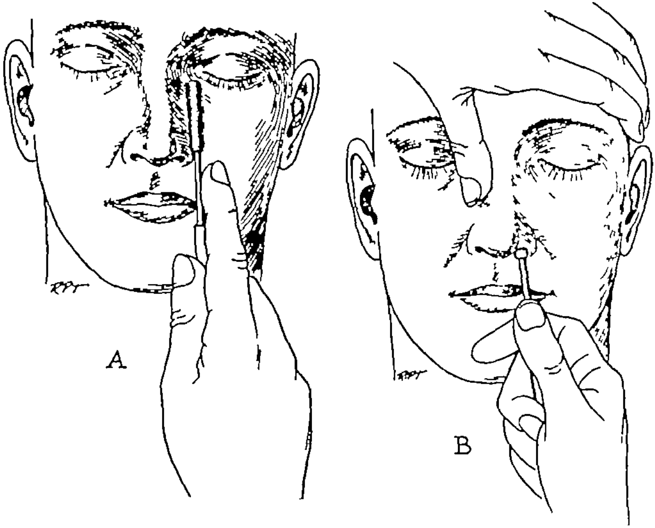


FIG 254

A. Reduction of nasal fracture. The elevator clothed with cotton, is placed along the lateral wall of the nose to a point below the medial canthus of the eye. The index finger is placed along the side of the elevator serving as a guide when the elevator is introduced.

B. The nasal arch is raised thus reducing the fractured fragments.

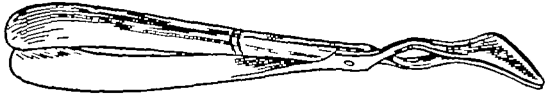


FIG 255 Modified Asche forceps for correcting position of septal fragments

which is unaccompanied by distinctive clinical manifestations. Occasionally in a clinically evident nasal fracture the radiological report is negative for fracture in the occipitomental views. Gillies and Millard (1957) have suggested increasing the backward tilt of the occipitomental view of 15 30 and 45 These positions may reveal fracture lines and displacement not shown in the usual occipitomental view The lateral view may show a fracture line but does not indicate the degree of displacement The roentgenogram reveals the extent of the displacement in simple or comminuted nasal fractures (*see Fig 219 see also Chapter 13*).

TREATMENT

Reduction of fractured nasal bones is

usually a simple procedure if undertaken soon after injury and previous to the onset of swelling Special measures are necessary to insure adequate reduction and immobilization in comminuted or compound fractures.

Anesthesia

Local anesthesia may be employed for adult patients a short general anesthesia such as light nitrous-oxide-ether or Pentothal sodium is preferred for children and highly sensitive adults. In simple fracture dislocation the anterior ethmoidal nerve is anesthetized by topical application of a 10 per cent cocaine solution diluted in an equal volume of adrenaline solution (1/1000) beneath the nasal bridge with applicators or cotton strips this is supplemented, if necessary by an injection of a solution of procaine-adrenaline under the soft tissues along the sides of the nose General anesthesia with intratracheal intubation may be required in complicated fractures. Cocaine packs are contraindicated in raw lacerated bleeding areas because of too rapid absorption of the drug

Depressed Fractures and Fracture Dislocations

The reduction of relatively uncomplicated nasal fractures such as the depressed fracture and fracture-dislocation of the nasal bones can be accomplished under local anesthesia. A thin layer of cotton moistened in saline and covered with petrolatum is wrapped tightly around the blunt end of a long periosteal elevator the use of cotton and petrolatum minimizes trauma to the nasal mucosa. The instrument is introduced into the nasal fossa well under the depressed bone, the nasal arch is raised and the displaced bone is replaced by digital pressure (Fig 254) The elevator is levered upward using the upper non fractured portion of the nasal bones as a fulcrum Manipulation with an Asche type forceps (Fig 255) is also employed to reduce a fractured

Fig 256 Walsham forceps (*above*) Walsham forceps being used for reduction of nasal bone fracture (*below*).

or dislocated septum by elevating the upper fragment of the septum correcting over riding fragments and replacing the septum in the groove in the vomer Walsham's forceps (Fig 256) right and left, are of assistance in straightening the lateral bony walls. One branch of the forceps is covered with rubber tubing to avoid injury to the skin It is advisable to pack the nose with petrolatum gauze if profuse and continued hemorrhage occurs after reduction of the fractured nasal bones.

Molded Nasal Splint

An external splint is applied to maintain the corrected position of the displaced nasal bones The nasal arch tends to revert to the displaced position if a splint is not used because of the spring like leverage of the septum especially when correction has been delayed for a few days.

Flat soft metal (22 gauge) shaped like an hourglass, is bent so that the lower portion conforms to the general shape of the nose

and the upper rests flat against the forehead The metal serves as a tray for a small quantity of dental compound softened in warm water and spread over the inner side of the splint (Figs 257 258) which is adjusted and molded to the nose thus establishing equal pressure on all sides. The appliance is retained above and below by strips of adhesive tape which are attached across the forehead and over the cheeks beneath the orbits. The splint is not disturbed for five days, at which time the nose is usually free from inflamation and edema

A smaller version of this appliance (Converse) without the upward frontal extension serves as an adequate splint.

If dental compound is not available, a splint can be made of plaster bandage.

Intranasal Packing

Intranasal packing with petrolatum gauze strips assists in maintaining the reduce position of the depressed fragment of nasal bone lateral cartilage and fractured septal cartilage. We have used a prepared packing of gauze impregnated with Aureomycin ointment. The packing should be introduced into the nasal fossa first along the floor of the nose and gradually built up between the middle concha and the septum to the undersurface of the depressed nasal bone and lateral cartilage. The packing is

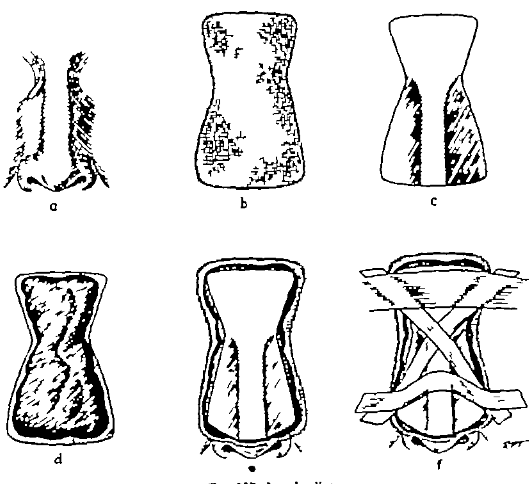


Fig 257 Nasal splint

A. The nose
B. A piece of lint is applied over the nose in order to protect the skin.
C. A piece of soft metal, gauge 22, is cut and shaped.
D Softened dental compound is spread over the metal splint.
E. Splint applied to the nose.
F Splint retained with adhesive tape.

retained for a period of at least five days. Intranasal packing is usually employed in conjunction with an external splint of dental compound.

The Kazanjian Nasal Fracture Splint

This splint was designed to assure the desired amount of continuous force against the lateral aspect of the nose at any selected point (Fig 259) The splint consists of an oblong-shaped metal frame the lower surface is supplied with a round bar about one fourth of an inch in thickness. The frame is embedded in dental compound spread over the forehead. The frame and compound are retained securely with the aid of adhesive tape passed around the head (Fig 260) The horizontal bar of the splint is not covered with dental compound but is left exposed for the attachment of a universal joint which can be passed freely

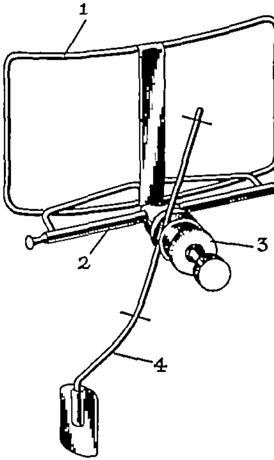


Fig 259 This splint may be anchored to the forehead as shown in Figure 260 It consists of a metal frame (1) of a horizontal bar (2) to which is attached a joint (3) The arm (4) is held by the joint and may be placed in the desired position by varying the position of the joint (3)

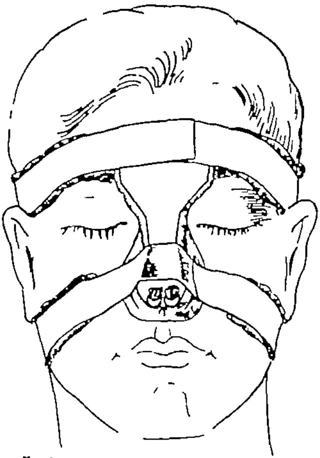


Fig 258. Nasal splint. The splint has been applied in the manner shown in Figure 257 It provides firm fixation of the underlying nasal framework. (V H. Kazanjian, Laryngoscope, 43 955 1933)

along the bar and then secured either to the right or the left of the median line (Fig 261) A vertical bar is attached to this joint the lower end consisting of a flat base covered with soft dental compound pressed against the side of the nose. Elastic bands are employed to exert pressure against the side of the nose gentle pressure should be applied for the splint is employed only to maintain the fractured bones in their corrected positions.

Comminuted Nasal Fractures

Comminuted fractures are generally characterized by marked flattening of the nasal bridge The fragments may be elevated satisfactorily if treated while the fragments are still loose. Additional support is required for a few days to immobilize the fragments

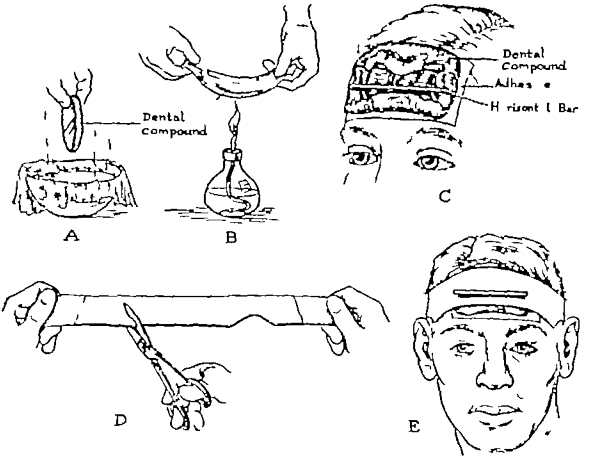


FIG 260 Drawing showing the method of application of the Kazanjian splint.
A. Dental compound is softened in hot water
B. Dental compound is passed over an open flame to make it more adherent
C. The frame of the splint is embedded into the dental compound on the forehead leaving the hori zontal bar exposed.
D Method of preparing adhesive tape to be placed around the head.
E. Adhesive tape anchoring the frame of the splint on the forehead A plaster bandage may also be used to hold the frame in position.

in the corrected position In some comminuted fractures intranasal packing used in combination with the molded nasal splint previously described is adequate to maintain the alignment of the fragments. The nasal dorsum tends to sink backward after reduction in markedly comminuted fractures with multiple fragments. Additional support is required to maintain suitable projection of the nasal bridge in such comminuted and telescoping type fractures. Nasal packing alone is not sufficiently effective to maintain the position of the fragments. Two other methods, the suspension and the wired plate methods can be employed

The Suspension Method

A wire appliance is employed as an internal support to elevate and immobilize the comminuted fragments of a nasal fracture Wire 14 gauge 5 cm long is bent to form a U Small metal hooks are soldered to one of the arms of the U A small piece of dental compound is softened and added to the smooth arm of the U wire (Fig 262) This is then introduced into the nose well up under the comminuted nasal bones, and pressed against the displaced fragments in order that the soft plastic dental compound may be molded to the inner surface of the nose The mold and wire are then removed and re inserted into the nose after

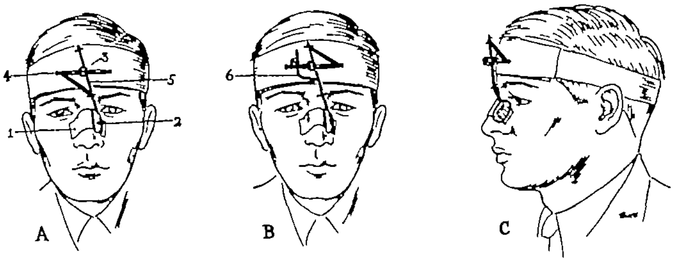


Fig 261 Placing of splint shown in Figure 259

A. The skin of the nose is protected by adhesive (1) a small pad of compound has been molded to the nose after being placed over the pad of the arm (2) the joint (3) is placed in the position best suited for the case. Elastic pressure is exerted between the frame (4) and the arm (5)

B. To protect the nose from excessive pressure the stop (6) may be applied. Note alternate position of elastic band.

C. Lateral view of the appliance.

trimming the surplus compound A bar (10 gauge wire) with a hook on its lower end is extended from the forehead to the nose and is retained by the cranial fixation appliance described previously (Fig 261) A small elastic band connects the intranasal and extra nasal attachments (Fig 262) The force exerted by the elastic is slight, merely enough to retain the position of the fragments.

The Wired Plate Method

This method is of particular value in comminuted nasal fractures of the telescoping type, with backward displacement into the interorbital space In crushed splayed out fractured structures around the ethmoids with widening of the nasal bridge at the level of the intercanthal line, the nose is elevated and the structures in the region of the medial canthus can be pinched together between the forefinger and thumb

The comminuted fragments at the upper part of the nose are manipulated by placing the thumb and the index finger over the lacrimal bones in order to bring the bony structures together The position of the fragments can be maintained by two plates placed on each side of the bony bridge of

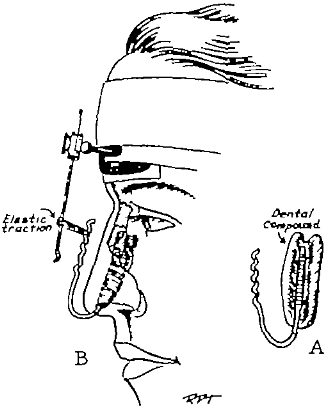


Fig 262 U-splint for suspension of comminuted nasal bones.

A. Softened compound is placed over one branch of the splint. This branch is then introduced into the nasal cavity and molded to the undersurface of the nasal bridge.

B. Suspension and elevation of the comminuted bony bridge is obtained by elastic traction utilizing the appliance shown in Figures 259 260 and 261

Fig 263 The wired plate method in a comminuted nasal fracture

A. Typical appearance of a comminuted fracture of the nasal bones with telescoping backward into the ethmoid

B. Fixation of the comminuted fragments obtained by the wired plate method.

C. Result obtained after consolidation of the fragments (courtesy of Dr W C. Huffman)

the nose (Fig 263) Using a large 3/8 curved cutting needle threaded with stainless steel wire size 32 the needle is introduced through the comminuted lateral wall of the nose above the medial canthus of the left eye as far back as possible and is then passed through the comminuted fragments, through the nasal cavity and brought out above the inner canthus on the right side as far back as possible The wire suture is threaded through a small lead or acrylic plate which is perforated for this purpose (Fig 263) The position of the needle is then reversed and the needle is carried through the right lateral wall to the left. Stainless steel wire is then tied over the left plate. The suture is pulled tight enough to lend support to the nasal structures (Fig 264)

The aim of fixation close to the attachment of the medial palpebral ligament is to maintain reduction of the bone fragment to which the ligament is attached. Lateral displacement of this fragment causes widening of the intercanthal region and the peculiar deformity of the inner canthus which occurs in such cases. Maintaining fixation of the nasal fragments for a period of a week insures consolidation in correct alignment.

Compound Nasal Fractures

In addition to reducing the fracture, special attention to the soft tissue wounds avoids unsightly scars resulting from compound fractures (Fig 265) Lacerations of the inner lining of the nose should be sutured to prevent stenosis and the position maintained by means of intranasal packing Alignment of the bones must precede suture of the soft tissues in compound fractures of the nose reduction may be observed through the open wound in some cases. The muscle layer over the bony bridge is sutured with fine plain catgut sutures before closing the skin wound.

Fractures and Dislocations of the Septal Framework

The septum can be straightened and replaced soon after injury this procedure should also be incorporated in nasal bone reduction The elevator used for reduction of the nasal bones raises the septum at the same time correction of the position of the

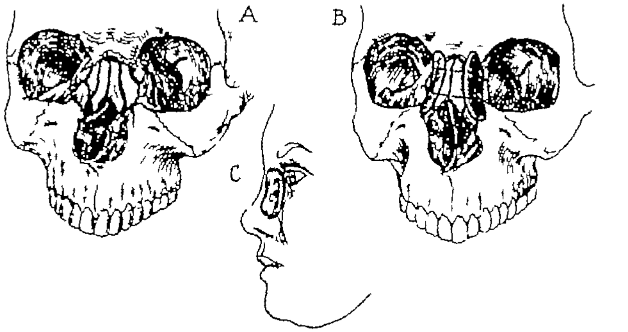


FIG 264 The wired plate method in comminuted nasal fractures (see Fig 263)

A. Diagramatic representation of a comminuted fracture of the nasal bones with telescoping backward into the ethmoid

B. Showing the method of providing fixation of the comminuted fragments by the wired plate method

C. Profile view showing the wired plate in position.

septum is completed with a special Ashe type forceps (Fig 255) The re aligned septal fragments are maintained by intranasal packing The mucoperichondrium heals rapidly if correction is delayed it may not be possible to obtain the desired result. When there is marked displacement and overlapping of septal fragments, exposure of the septal framework by subperichondrial elevation, as for a submucous resection affords a more satisfactory exposure Such cases may require an immediate submucous resection of the nasal septum to re-establish adequate nasal airways and also to permit re-aligning the external bony structures Late submucous resection of the nasal septum is required to restore an adequate nasal airway

Hematoma of the Septum

A hematoma may form between the septal mucosa and the cartilage in fracture or dislocation of the septum or simply as a result of bending the septal cartilage. Hematoma of the septum is often bilateral for fracture of the septum permits passage of the blood from one side to the other In spection reveals a double-sided fluctuant swelling of the septum covered by red and edematous mucosa. Septal hematoma may result in permanent thickening of the septum thus blocking the nasal airway Pressure necrosis of the cartilage is caused by a voluminous hematoma and is a more seri ous complication. Infection of the hema toma and septal abscess may result in destruction of septal cartilage and collapse of the nasal bridge a complication observed particularly in children

Septal hematoma is treated by incising through the mucoperichondrium to permit drainage and suction is employed to evac uate the blood. In order to prevent refilling of the cavity with blood or serum a small piece of mucoperichondrium may be re moved with a ring punch in order to provide an adequate opening for drainage The mu coperichondrium is pressed firmly against the cartilage by nasal packing A drainage incision is established on each side of the septum in bilateral hematoma

We have performed an immediate sub-

FIG 265 (*Top left*) Compound comminuted fracture of the nasal bones, laceration of soft tissues and loss of the left eye. (Ten days after injury the left eye was enucleated and an artificial eye implanted.)

(*Top right*) Result obtained after reduction of fracture and suture of wounds

(*Bottom*) Roentgenogram showing comminuted fracture of nasal bones with marked displacement to the left

(V. H. Kazanjian, Tr. Am. Acad. Ophth. & Otol. 38: 275, 1933)

mucous resection of the fractured septal framework in a number of cases. This approach affords a wide exposure between the mucoperichondrial flaps and permits removing obstructing fractured septal fragments and blood clots between the flaps. A horizontal incision through the mucoperichondrial flap along the floor of the nose assures drainage and prevents accumulation of blood between the flaps

Delayed Reduction of Nasal Bone Fractures

Because of severe concomitant injuries or in the absence of early diagnosis treatment of a fracture of the nasal bones may be unavoidably delayed for a number of days after the injury Considerable swelling resulting from trauma inflammatory reaction and hematoma may obliterate all landmarks (Fig 266) In such cases, it is advisable to administer antibiotics, relieve nasal obstruction by removal of clots and by vasoconstrictors and await the subsiding of the swelling Satisfactory treatment can be achieved by simple elevation and manipulation of the fragments during the first days after fracture.

It is difficult to obtain reduction by the simple manipulation methods previously described when the reduction of a nasal fracture has been delayed for a period of one week or longer An operation is necessary to completely free the fractured nasal bones and septal framework in order to obtain adequate re alignment The surgical procedures for the re alignment of the mal united fracture of the nasal bones is described in Chapter 22

Purposeful Delay in Nasal Bone Fracture Reduction

The entire nasal area and a large portion of the adjacent facial region is extremely edematous and all landmarks in the nose are lost when the patient with a fractured nose is seen later than 24 hours after the

FIG 266 Appearance of patient three days after injury fracture of the nasal bones with suppurating hematoma of the nose.

fracture The swelling is sometimes due not only to edema but to an extensive hematoma under the soft tissues of the nose. The method of treatment in such cases consists of placing the patient on antibiotic therapy draining the hematoma and treating the patient expectantly until the swelling is reduced This may entail a delay of 3 or 4 days but the nasal reduction can then be done under more favorable circumstances.

Infection of a nasal hematoma may complicate the treatment. The patient shown in Figure 266 was first seen three days after a nasal fracture which was accompanied by a large hematoma. The hematoma had become infected and the patient presented the classical signs of acute inflammation with marked redness and swelling, tenderness and elevation of temperature. Antibiotics were employed for a period of three days, the signs of infection subsided and the swelling was reduced the reduction of the nasal bone fragments could then be done adequately

COMPLICATIONS IN NASAL FRACTURES

Early Complications

Simple fractures do not usually result in serious complications temporary edema and ecchymosis of the skin of the nose and eyelids usually disappear after a few days Epistaxis at the time of injury usually ceases spontaneously Repeated epistaxis may occur however complicating the treatment because nasal packing must be introduced without interfering with the realigned fragments. The bleeding area can be localized by vasoconstriction and cauterized with silver nitrate, trichloroacetic acid or by an electrocautery Hematoma of the septum is rare unless treated early however it may lead to abscess and necrosis of the septal cartilage and eventual depression of the dorsum of the nose. Infection may occur as a result of hematoma under the soft tissues covering the nose antibiotics, incision and drainage are necessary in such conditions.

Late Complications

Hematoma of the septum results in subperichondrial fibrosis, increased thickness of the septum and nasal obstruction The thickness of the septum may exceed 1 cm in patients who have suffered repeated nasal trauma as for example pugilists. Nasal obstruction in such cases is marked and requires subsequent submucous resection of the septal framework. Deviation of the septum resulting in nasal obstruction requires submucous resection of the deviated septal framework (see Chapter 22)

Adhesions may form between the torn mucoperichondrium of the septum and the mucous membrane of an injured turbinate These synechiae form rapidly and should be anticipated. Intranasal packing retained for 4 or 5 days, usually prevents such adhesions. Synechiae between the septum and the turbinate require the cutting through and placing of a packing between the structures until epithelization occurs.

Obstruction from a malunited segment of bone from the edge of the pyriform aperture is relieved by resection of the bone Atresia and stenosis of the vestibule and internal naris due to *loss of nasal lining* is relieved either by Z plasty or by a nasal epithelial inlay (see Chapter 22)

Osteitis and osteomyelitis are unusual following nasal bone fractures. The telescoping type of comminuted fracture of the nasal bones may be associated with serious injuries of the interorbital space lacrimal sac involvement and cerebrospinal rhinorrhea The treatment of these cases is discussed in Chapter 10

Delayed union is unusual for most nasal bone fractures consolidate within the period of a week. Non-union is practically unknown except for detached fragments in comminuted fractures that become separated from the main bony mass and remain attached by fibrous tissue only

Malunion of nasal fractures, resulting in nasal deviation or depression requires corrective surgery The surgical treatment of malunited fractures of the nasal bones *resulting in nasal deviation or depression* of the nasal dorsum is described in Chapter 22.

9

FRACTURES OF THE ZYGOMA

ANATOMICAL CONSIDERATIONS

The zygoma is a buttress of the facial skeleton it has temporal orbital maxillary and frontal processes and is described as quadrilateral in shape. The bone joins the zygomatic process of the maxilla anteriorly and the zygomatic process of the temporal bone posteriorly completing the zygomatic arch which is thus formed by contributions from three bones—maxillary zygomatic and temporal (Fig 267) A convexity on the outer surface of the zygoma known as the tuberosity forms the point of greatest prominence of the cheek. The zygoma articulates with four bones, the frontal sphenoid temporal and maxilla (Fig 267) participates in the formation of the lateral wall and floor of the orbital cavity the maxillary sinus the zygomatic and temporal fossae and provides attachment for the masseter temporalis and zygomaticus muscles and the zygomatic head of the quadratus labii superioris muscle

SURGICAL PATHOLOGY

Fracture-dislocation of the zygoma occurs frequently Although it is a sturdy bone, the processes of the zygoma are subject to separation from the frontal temporal sphenoid, and maxillary bones, with the zygoma usually displaced downward inward and backward (Fig 268) Downward displacement may be marked, resulting in separation of frontozygomatic junction. Continuity of the floor of the orbit is also disrupted a step being formed along the inferior rim of the orbit between the zygoma and maxilla (Fig 269) Rotation of the entire body of the zygoma may also occur the maxillary process of the zygoma being pushed into the maxillary sinus causing depression of the infra-orbital area the zygomatic process protruding laterally (Fig 270) The bone may be pushed inwardly or laterally in other varieties of fractures (Fig 271*A*)

Because the zygoma forms the bony wall of the superolateral portion of the maxillary sinus, fracture causes a tearing of the antral mucosa resulting in hemorrhage in the sinus bleeding from the nose may be an indication of blood escaping through the ostium in the middle meatus.

Crash injuries often cause comminuted fractures in which the rim and floor of the orbit are reduced to splinters the anterior and posterior walls of the maxillary sinus are shattered bone fragments are lodged in the sinus and the main fragment of the body of the zygoma is rotated.

Because the zygoma forms an appreciable portion of the skeletal framework of the floor and lateral walls of the orbit displacement of the bone produces varied degrees of disorganization of the orbital cavity and disturbs the function of the eyeball

When the lower rim of the orbit is displaced backward, tension on the septum orbitale attached to the rim results in a downward pull upon the lower eyelid (see Fig 602 Chapter 21).

The lateral palpebral ligament is attached to the orbital surface of the frontal

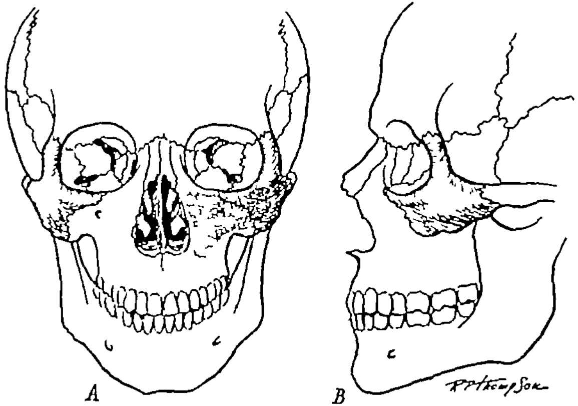


Fig 267 The zygoma articulates with the frontal sphenoid, temporal bones and the maxilla
A. Dotted area shows portion of zygoma and maxilla occupied by the maxillary sinus.
B. Zygoma is shaded.

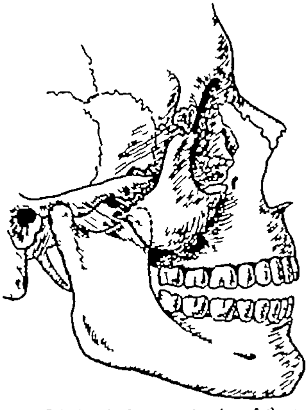


Fig 268. Simple fracture-dislocation of the zygoma with downward and inward displacement.

process of the zygoma and to the rim posteriorly (Fig 272). The thickening of Tenon's capsule known as Lockwood's suspensory ligament is also attached to the orbital surface of the frontal process of the zygoma immediately below the lateral palpebral ligament. Displacement of the frontal process of the zygoma such as occurs in fractures with frontozygomatic separation causes a downward displacement of these ligamentous attachments, the lateral canthus and the eyeball

Fragmentation of the bony floor of the orbit may permit the orbital contents to sag into the maxillary sinus. The downward displacement of the orbital contents may be accentuated by the subsequent traction of scar tissue formed during the healing of damaged soft tissues. Diplopia is a frequent consequence of ptosis of the eyeball

When bony displacements enlarge the orbital cavity the orbital fat distributed in

FIG 269 Roentgenogram showing inward and downward displacement of the zygoma. A notch is noted along the inferior rim of the orbit between the zygoma and the maxilla.

the larger cavity no longer maintains the normal degree of protrusion of the globe, and the eye becomes enopthalmic. Enophthalmos also results from the escape of orbital fat into the maxillary sinus when the floor of the orbit is disrupted the periorbital and mucosal lining of the maxillary sinus are torn permitting penetration of orbital fat into the maxillary sinus.

Limitation of jaw movement may be due to impingement of the zygomatic bone upon the coronoid process of the mandible when downward excursion of the mandible is attempted, the coronoid process strikes the depressed bone. The temporalis muscle is compressed by pressure upon the coronoid process. Inability to open the mouth after a fracture of the zygoma is usually a sign of depressed fracture of the zygomatic process of the temporal bone and the temporal

FIG 270 Flatness in the right zygomatic region resulting from depression of the zygoma into the maxillary sinus as a result of a fist blow

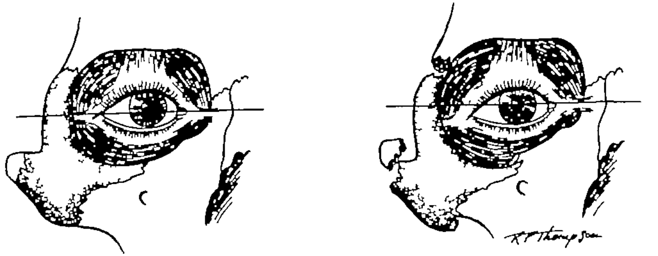
FIG 271 Roentgenogram showing bilateral fracture of zygoma resulting from an automobile accident

A. Fracture with outward displacement of the zygoma exaggerating the contour of the zygomatic prominence

B. Typical V-shaped fracture of the zygomatic arch with displacement toward the temporal fossa. In this type of fracture pressure on the coronoid process limits the motion of the mandible

process of the zygoma the structures often are referred to clinically as the "zygomatic arch (Fig 271B)

The infra-orbital foramen and the infra orbital nerve located close to the junction of maxilla and zygoma may be injured as a result of a zygomatic fracture Injury of the nerve within the canal occurs more frequently (Fig 273) Anesthesia in the area of distribution of the infra-orbital nerve is usually temporary when compression of the nerve by bone fragments occurs within the canal however infra-orbital anesthesia may be permanent



A B

FIG 272. When the frontal process of the zygoma is displaced downward, the lateral palpebral ligament and canthus of the eye follow

A. Drawing of normal orbit.

B. Downward displacement of the eyeball as a result of frontozygomatic separation.

EXAMINATION AND DIAGNOSIS

Clinical Examination

The striking feature noted in the first few hours after accident in a patient who has suffered fracture of the zygoma with displacement is the loss of normal prominence of the cheek bone (Fig 274) the one-sided flatness of the face is often concealed by soft tissue swelling (Fig 275) The eyelids are markedly swollen and ecchymotic and the eyeball reveals subconjunctival hemorrhage. The patient may complain of pain, particularly when attempting to open the mouth. Bleeding from the nose is frequent but of short duration unilateral nosebleed from the nasal airway may occur on the affected side.

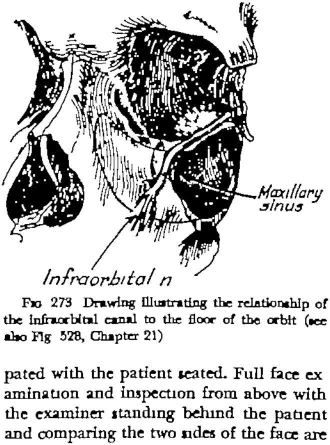


FIG 273 Drawing illustrating the relationship of the infraorbital canal to the floor of the orbit (see also Fig 528, Chapter 21)

Some patients complain of double vision. The eyeball is displaced downward and the skin fold of the upper lid appears deeper than usual in fractures with gross downward displacement. Shortening of the lower eye lid with a tendency to ectropion is occasionally observed. This deformity indicates a backward or downward displacement of the lower orbital rim causing tension upon the insertion of the septum orbitale (see Fig 602, Chapter 21)

The face should be examined and palpated with the patient seated. Full face examination and inspection from above with the examiner standing behind the patient and comparing the two sides of the face are helpful Points of tenderness are elicited at the lines of fracture, at the frontozygomatic junction the zygomatico-maxillary junction and the temporozygomatic junction. The fracture is defined by palpating the unaffected and the injured orbital margins simultaneously It is often possible to detect a separation at the junction of the zygoma

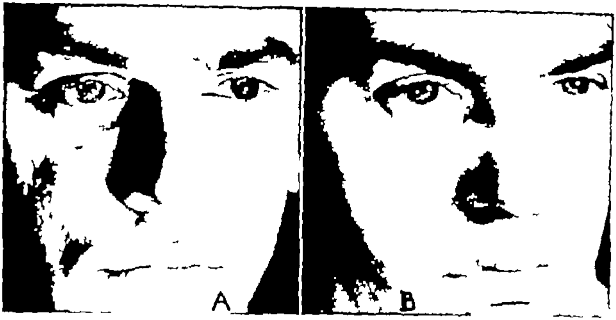


FIG 274 Fracture of the zygoma
A. Note the depression in the upper and lateral portion of the cheek and subconjunctival hemorrhage
B. Restoration of contour after reduction of fractured zygoma through the temporal route.

FIG 275 Typical appearance of patient with fracture of the left zygoma showing edema and ecchymosis around the eye

FIG. 276 Patient with a fracture of the zygomatic arch pressing against the coronoid process and causing limitation of jaw motion.

and maxilla or the zygoma and frontal bone on the injured side.

A slight depression noted in the area of junction of the temporal process of the zygoma with the zygomatic process of the temporal bone may be an indication of a depressed fracture Restriction of mandibular movements indicates displacement of the posterior portion of the body of the bone or the arch denoting pressure upon the coronoid process (Fig 276)

Abnormal mobility is rarely elicited in most fracture-dislocations of the zygoma which are impacted but mobility and crepitation occur in comminuted fractures.

The patient may have noted numbness

in the upper lip on the fractured side. Palpation of the upper lip discloses anesthesia in the area of distribution of the infra orbital nerve. Deviation of the philtrum toward the unaffected side and slight drooping of the upper lip on the side of the fracture are seen occasionally due to downward displacement of the origins of the zygomaticus and zygomatic head of the quadratus labii superioris muscles.

A technique for evaluating the displacement of the zygoma is to introduce the index finger into the upper oral vestibule on the fractured side palpating the area of junction of the zygoma and maxilla. A groove, felt between the zygoma and maxilla on the unaffected side is absent in a depressed fracture.

In fractures associated with an extensive soft tissue wound damage to the bone can be seen through the open wound usually penetrating the maxillary sinus.

Roentgenographic Examination

Two roentgenographic positions are of particular value the Waters (Fig 269) and the Caldwell postero-anterior views (Fig 271) The Waters position is of assistance in detecting multiple fracture lines, separation at the frontozygomatic junction and depression of the floor of the orbit. The vertico-submental view assists in detecting fractures of the zygomatic arch. The laminograph is indispensable when orbital fractures are suspected (see Fig 288) see also Chapter 13)

TREATMENT

Most simple fractures usually respond to reduction without fixation. Others require fixation after open reduction These are comminuted fractures of the floor of the orbit which require the re-establishment of the continuity of the orbital floor

Reduction of Fracture Dislocations

Since Duverney (1751) first described the fracture numerous measures have been suggested to reduce the fractured zygoma.

Oral Approach (Keen 1909)

Under general anesthesia the mucobuccal fold lateral to the maxillary tuberosity is exposed intra-orally employing a cheek retractor A short elevator is passed upward behind the fractured zygoma through an incision made in the buccal mucosa above the tuberosity of the maxilla on the affected side (Fig 277) The instrument must be maintained close to the bone to avoid entering the fat pad in the temporal area Reduction of the fracture is accomplished by elevating the bone upward and outward a snapping sound may be heard when the bone is replaced The buccal incision need not be sutured The procedure is simple direct and rapid. Infection has not been observed to result from passage through the oral cavity

The intra-oral method is contraindicated in fractures of the zygomatic arch (Fig 271) for the masseter muscle interferes with manipulation of the fragment the temporal approach should be employed in such cases.

Temporal Approach (Gillies Kilner and Stone 1927)

The hair on the temporal region of the affected side is shaved. An incision about 2 *cm. in length, is made through the scalp and* the glistening surface of the temporal fascia is exposed (Fig 278) The skin incision is made parallel to the temporal vessels to avoid sectioning branches of the superficial temporal artery The temporal fascia is then incised and the fibers of the temporalis muscle are exposed It is important to remember that the superficial fascia can be differentiated from the deeper temporal fascia exposed by blunt dissection the deeper fascia appears pearly white and tough. The fascia is then incised and an elevator placed between it and the muscle. Because the temporal fascia is inserted along the upper margin of the zygomatic arch an instrument placed laterally to the fascia will not penetrate the zygomatic fossa Gillies has emphasized the importance of placing the lever

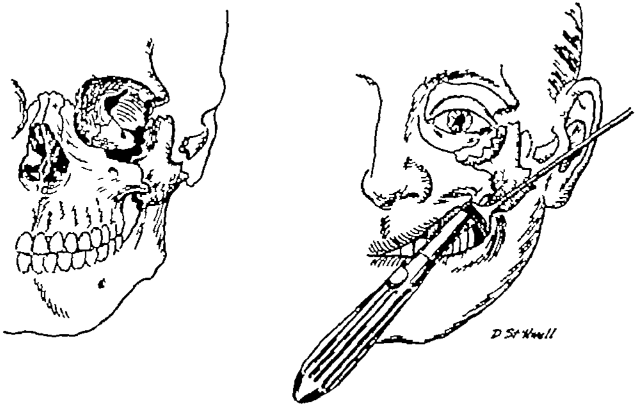


Fig. 277 Oral approach for reduction of fractured zygoma

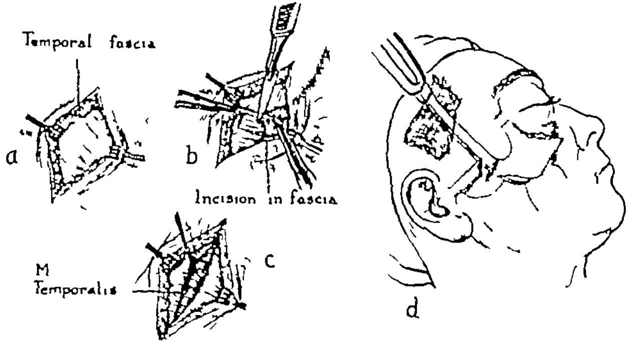


Fig. 278. Temporal approach for reduction of fractured zygoma

A. Incision through scalp, exposing temporal fascia.
B. Fascia incised
C. Cleavage plane between temporal fascia and temporalis muscle
D. Elevator inserted beneath zygoma.

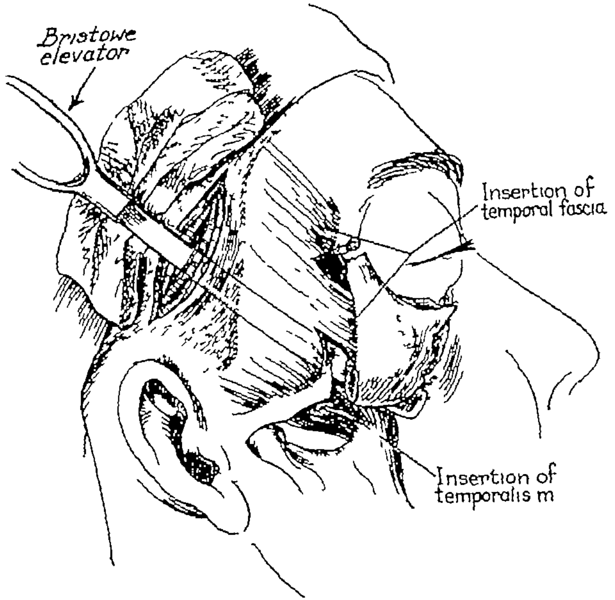


FIG. 279 Drawing illustrating the attachment of the temporal fascia along the upper margin of the zygomatic arch. To penetrate into the zygomatic fossa the instrument must be placed on the deep surface of the temporal fascia.

under the full thickness of the temporal fascia in order to avoid penetrating into the space between the layers of the temporal fascia which divides immediately above the zygoma into outer and inner layers which go to the borders of the bone A cleavage plane established between the muscle fibers and the temporal fascia leads directly under the zygomatic arch to the medial surface of the bone (Fig. 279) The zygoma is raised with a long, flat elevator and returned to position employing leverage the instrument resting on the posterior margin of the scalp incision and the skull Gauze is placed under the instrument to prevent bruising the scalp The movement of the bone is followed and controlled by the fingers. The fascia and scalp are sutured following reduction The operation is simple and rapid and is particularly effective when strong leverage is required to reduce a partially consolidated fracture.

Maxillary Sinus Approach (Lothrop 1906)

A window is established through the lateral wall of the inferior meatus and a spe-

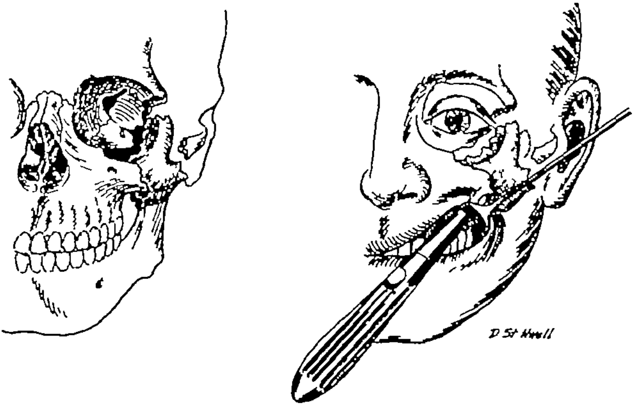


FIG. 277 Oral approach for reduction of fractured zygoma

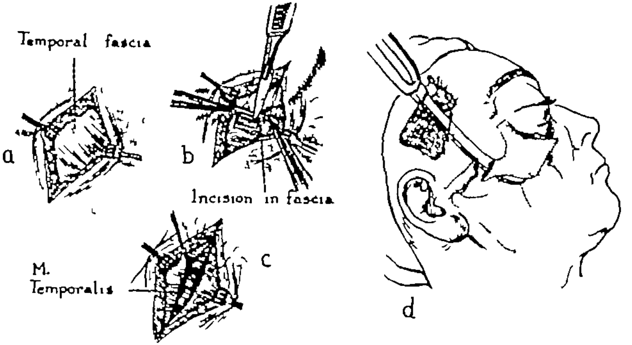


FIG 278. Temporal approach for reduction of fractured zygoma

A. Incision through scalp exposing temporal fascia.

B. Fascia incised.

C. Cleavage plane between temporal fascia and temporalis muscle.

D Elevator inserted beneath zygoma.

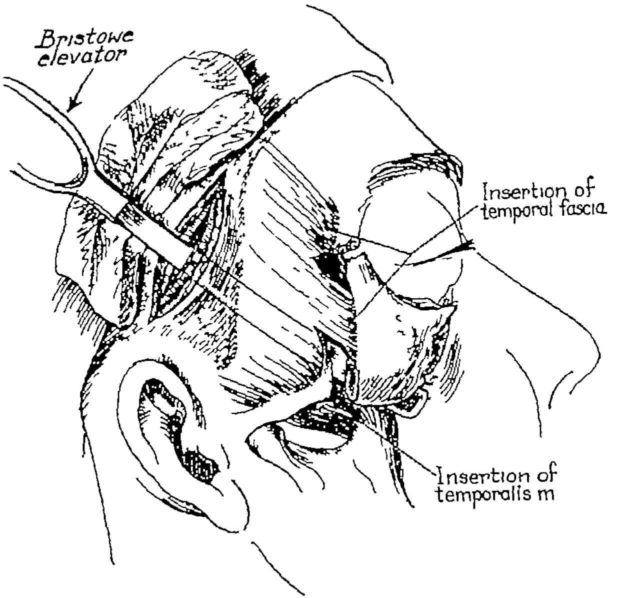


Fig 279 Drawing illustrating the attachment of the temporal fascia along the upper margin of the zygomatic arch. To penetrate into the zygomatic fossa the instrument must be placed on the deep surface of the temporal fascia.

under the full thickness of the temporal fascia in order to avoid penetrating into the space between the layers of the temporal fascia which divides immediately above the zygoma into outer and inner layers which go to the borders of the bone. A cleavage plane established between the muscle fibers and the temporal fascia, leads directly under the zygomatic arch to the medial surface of the bone (Fig 279) The zygoma is raised with a long flat elevator and returned to position employing leverage the instrument resting on the posterior margin of the scalp incision and the skull. Gauze is placed under the instrument to prevent bruising the scalp The movement of the bone is followed and controlled by the fingers. The fascia and scalp are sutured following reduction. The operation is simple and rapid, and is particularly effective when strong leverage is required to reduce a partially consolidated fracture.

Maxillary Sinus Approach (Lothrop 1906)

A window is established through the lateral wall of the inferior meatus and a spe-

cially curved trocar is introduced into the maxillary sinus. This instrument is then rotated upward and outward, levering the depressed fractured zygoma into the correct position.

Reduction of Comminuted Fractures

Additional support is necessary in comminuted fracture of the zygoma to control the position of the fragments and to assure restoration of contour and function. The comminuted type of fracture involving the floor of the orbit is of particular gravity for diplopia and enophthalmos may be the result of such fractures. A number of methods have been employed for the treatment of these fractures these include the maxillary sinus approach the intra-oral exposure technique the suspension method and direct interosseous wiring

Maxillary Sinus Approach through the Canine Fossa

The maxillary sinus approach should be employed in comminuted fractures of the floor of the orbit. An intra-oral incision is made through the vestibular mucosa over the canine fossa. The periosteum over the area of the canine fossa is raised and the soft tissues of the cheek are retracted upward with an angular retractor Using a small osteotome, a window is established in the anterior wall of the maxillary sinus which is then entered blood clots and hematoma are aspirated from the cavity and the interior of the sinus is inspected. The floor of the orbit is examined and palpated with a finger to ascertain possible involvement of the orbital floor which may elicit a yielding feeling when the orbital contents are ptosed into the maxillary sinus as a result of the comminuted fracture.

When the orbital floor is fractured as evidenced by digital palpation the maxillary sinus may be packed to provide adequate suport until consolidation occurs. In severely comminuted fractures of the orbital floor with gross displacement of the orbital contents, the re-establishment of the con tinuity of the floor of the orbit may rec a more positive method of treatment employs a bone graft. The technique i scribed later in this chapter

The sinus is packed with gauze throu Penrose-type soft rubber drain or gauze impregnated with Aureomycin ment to achieve this purpose (Fig 28(nasoantral opening is established under inferior turbinate bone to assure s quent drainage the packing is remo through the opening Although such p ing has remained in the sinus for per of two weeks in some cases, sequelae as persistent sinusitis have not been served.

Intra-oral Exposure of the Zygoma an Maxilla

In comminuted fractures and in cer fracture-dislocations which are treated l reduction under direct vision after in oral exposure of the zygoma is of value (281) The zygoma and maxilla are expo by subperiosteal elevation of the soft tiss The incision in the mucosa is placed la ally to the frenulum on the affected (Fig 281*A*) After dissecting the muc from the orbicularis oris muscle the per teum is incised and elevated, exposing defect (Fig 281*B*) Wide exposure of anterior surface of the maxilla is obtain the zygoma may be approached by exte ing the periosteal elevation laterally T infraorbital nerve and vessels are avoi by carefully raising the periosteum arou the neurovascular bundle preserving its tachment to the elevated soft tissues (I 281*C*) which are raised with retractors, t obtaining a satisfactory exposure of maxilla and zygoma The bony defect n then be inspected inasmuch as adequ lighting of the area is provided

Following the intra-oral exposure alignment is achieved by means of levers under the zygomatic fragments. The red tion of the fragments is observed under s

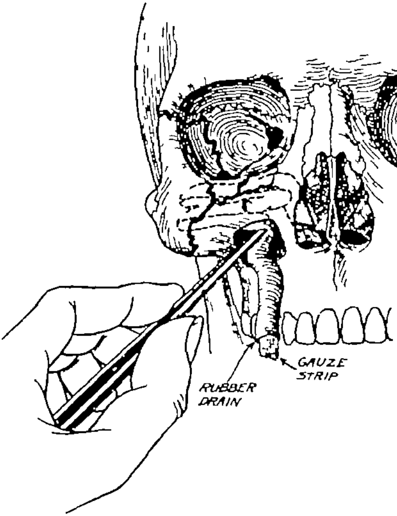


FIG 280 Packing of the maxillary sinus for support of comminuted fragments of the floor of the orbit. Packing is introduced inside a large Penrose drain and brought out through the nasoantral window

able illumination by means of a headlight. If reduction is not maintained because of the mobility of the fragments, one of the following methods should be employed.

Suspension Method (Kazanjian 1933)

The inferior orbital rim is exposed by the intra-oral route and a hole is drilled through the rim at a point just below the ridge. Exposure of the inferior orbital rim may also be obtained by means of a small incision through the lower portion of the lower eyelid. A fine stainless steel wire, passed through the hole, is brought out through the skin just below the infra-orbital margin the ends of the wire on the surface of the skin are then bent to form a hook A headgear or plaster headcap is employed. A wire is fixed to the headgear and passed vertically over the face small elastic bands connect the vertical wire to the hook extending from the skin The upward and outward traction thus effected retains the fragments (Fig 282) The appliance need not usually be worn more than two weeks the wire loop attached to the bone is then withdrawn

Direct Interosseous Wiring (Gill 1934)

When separation occurs at the frontozygomatic suture, direct interosseous wiring can be employed through a small external incision Reduction is obtained through the temporal or the oral approach. After exposing the fracture site through a small horizontally placed external incision a fine stainless steel wire is passed through drill holes in the bones and tightened to maintain the fragments (Fig 283) Direct wiring of the separated ends of the zygoma and

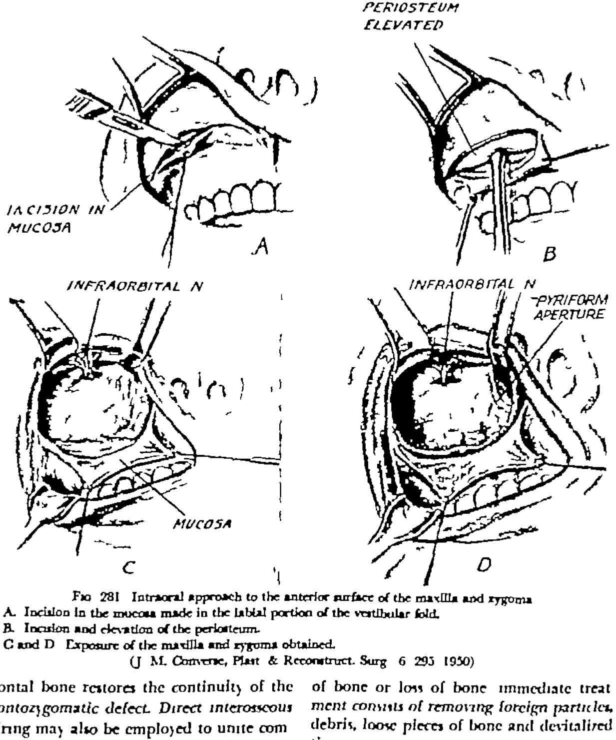


FIG 281 Intraoral approach to the anterior surface of the maxilla and zygoma
A. Incision in the mucosa made in the labial portion of the vestibular fold.
B. Incision and elevation of the periosteum.
C and D Exposure of the maxilla and zygoma obtained.
(J M. Converse, Plast & Reconstruct. Surg 6 295 1950)

frontal bone restores the continuity of the *frontozygomatic defect. Direct interosseous* wiring may also be employed to unite comminuted zygomatic fragments of the lower orbital rim This procedure is also used when other means of fixation fail to restore or maintain the continuity of the lateral orbital rim

Compound Comminuted Fractures of the Zygoma

Because such conditions are associated with soft tissue wounds and comminution of bone or loss of bone immediate treatment *consists of removing foreign particles,* debris, loose pieces of bone and devitalized tissue

Exploration of the depth of the soft tissue wound reveals the displaced bony fragment The fragments can be aligned by one of the methods previously described with the additional advantage of observing the reduction through the open wound Methods of fixation include packing the maxillary sinus, direct wire suspension or interosseous wiring

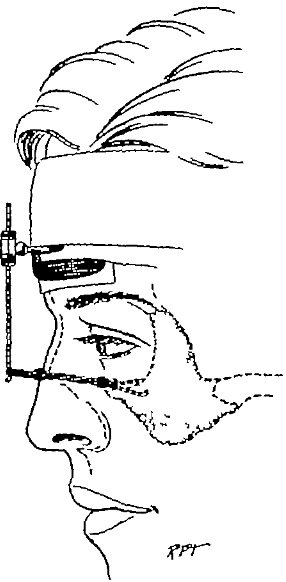


FIG 282. Elastic traction for reduction of zygomatic fractures. A hole is drilled through the orbital rim and a fine stainless steel wire is passed through the hole and brought out through the skin. The wire is connected to the suspension appliance by elastics. The latter is anchored to the forehead as described in Figures 260 and 261

Fixation of Zygomatic Fractures

Most fractures of the zygoma remain in the corrected position following reduction. In the typical fracture-dislocation treated early the bone snaps back and does not resume its faulty position Some degree of displacement is occasionally observed after reduction however and the postoperative appearance after the displacement may be disappointing

It is seldom possible to maintain adequate position in fractures with marked downward displacement of the bone and separation at the frontozygomatic junction without the use of direct interosseous wiring Adequate support should, therefore be provided Wire traction is employed when there is a tendency for backward displacement to recur following reduction traction maintains forward projection of the bone. Direct interosseous wiring is one of the most efficient methods of immobilizing bone fragments Buried stainless steel wire (28 Gauge) has been employed to fasten the fragments together and has proved satisfactory probably as a result of improved surgical technique and the protection afforded by antibiotics.

Complications are rarely caused by the presence of the wire even in compound fractures continued presence of the wire occasionally results in localized inflammatory reaction which necessitates its removal

Direct visualization by intra-oral exposure permits evaluation of the position and number of fracture lines, the degree of displacement, and also verification that the fragments are adequately reduced.

Delayed Treatment of Zygomatic Fractures

Fractures of the zygoma seen within a few weeks after injury may still be treated satisfactorily by simple methods of elevation One cannot be sure, however that the position of reduction will be maintained and additional methods of fixation are required. The intra-oral exposure of the zygoma is most helpful for this permits direct examination of the fracture lines and facilitates replacement of the bone by loosening the fibrous tissues and young callus using a narrow osteotome to loosen malunited bone.

COMPLICATIONS IN FRACTURES OF THE ZYGOMA

Early Complications

Early complications are usually of little consequence or disappear very soon after the injury Hematoma of the maxillary sinus does not require irrigation and drain

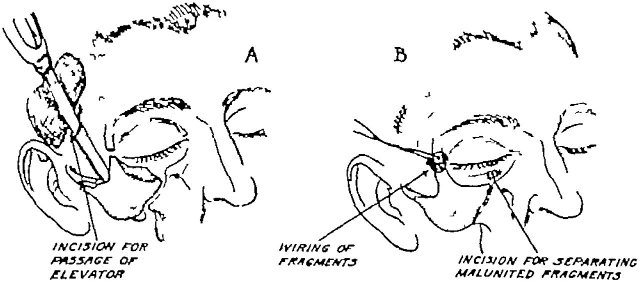


Fig 283. Direct interosseous wiring of fractured zygoma
A. Elevation of zygoma through the temporal approach.
B Wiring the frontozygomatic junction.

age as the blood is absorbed spontaneously Anesthesia in the area of innervation of the infra-orbital nerve is usually a temporary condition Infection may involve the maxillary sinus and surrounding soft tissues in comminuted and in compound fractures but is rare in simple factures. Acute sinusitis may develop as a result of the flare up of a pre-existing chronic sinusitis.

A rare but serious complication which we have observed in two cases, as a result of zygomatic fracture is immediate blindness, most probably attributable to a fracture extending to the optic canal thus involving the optic nerve

Enophthalmos and Diplopia in Fractures of the Orbital Floor

Complications such as enophthalmos and diplopia are encountered more frequently in comminuted fractures which involve the zygoma maxilla and floor of the orbit These complications have led us to reconsider some of the surgical aspects of these comminuted fractures and in particular their early treatment (Converse and Smith 1957)

The orbital contents are protected by the strong orbital arch of the frontal bone above the zygoma laterally the frontal process of the maxilla, medially and the relatively thick rim of the orbital floor inferiorly formed by the zygoma and maxilla (Fig 284)

The relatively thin bone below the orbital rim is formed by the anterior wall of the maxillary sinus. The orbital floor also consists of thin bone which in part separates the orbital cavity from the maxillary sinus this thin portion of the orbital floor is weakened further by the infraorbital groove or canal The orbital walls are thin in two additional areas, over the temporal fossa laterally and the lamina papyracea of the ethmoid medially these areas are readily demonstrated by transillumination of the dried skull

In fractures of the zygoma and maxilla with marked displacement of the orbital rim concomitant fracture of the thin orbital floor may be anticipated In fractures with slight displacement however the involvement of the weak areas of thin bone in the orbital floor is not always obvious. This has been demonstrated in observations made during operative procedures to restore the orbital floor by bone grafting after malunited fractures (Converse 1944

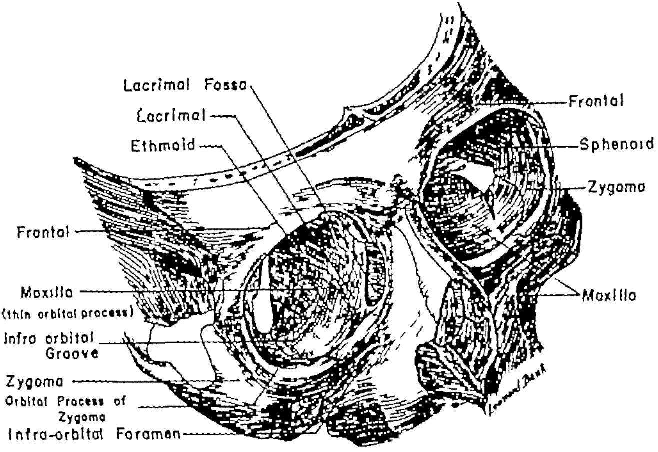


FIG 284 Drawing illustrating the anatomy of the bony orbit. The shaded area represents the thin portion of the floor posterior to the thick orbital rim.
(Figs. 284 to 287 from J M. Converse and B. Smith, Brit. J Plastic Surg., 9 265 1957)

Converse and Smith, 1950) Depression of the thin portion of the orbital floor was seen and in some cases a direct opening between the orbit and the maxillary sinus was visible

These observations lead us to believe that comminuted fractures of the thin portion of the orbital floor can occur by two different mechanisms (1) backward displacement of the strong bone forming the orbital rim which results in comminution of the thin bone into multiple small pieces and (2) increased internal orbital pressure caused by a blow on the soft tissues of the orbit thereby producing fracture of the weak area without affecting the more resistant orbital rim a type of fracture which we have referred to as the "blowout" fracture (Fig 285) This latter type of fracture may be caused by large, non penetrating objects such as the human fist, a baseball a snowball or a cricket ball in one of our cases the fracture was caused by a ball used in the Irish game of hurling (Smith and Regan, 1957) We have reproduced this type of "blow-out fracture experimentally on the cadaver

Downward displacement of orbital contents into the maxillary sinus occurs by three types of mechanisms (1) Gross displacement of the bones of the orbital floor particularly when these bones are comminuted and ptosis of the orbital contents by gravity Additional displacement is caused by accumulation of blood and edema fluid in the injured peri-orbital tissues (2) Additional depression of the orbital contents during the healing period is due to the pull of the maturing scar tissue on the loose fragments of the orbital floor (3) Escape of the orbital contents through a rent in the orbital floor due to increased intra-orbital pressure occurs in the "blow out" type of fracture.

Enophthalmos and diplopia are frequent complications of such fractures.

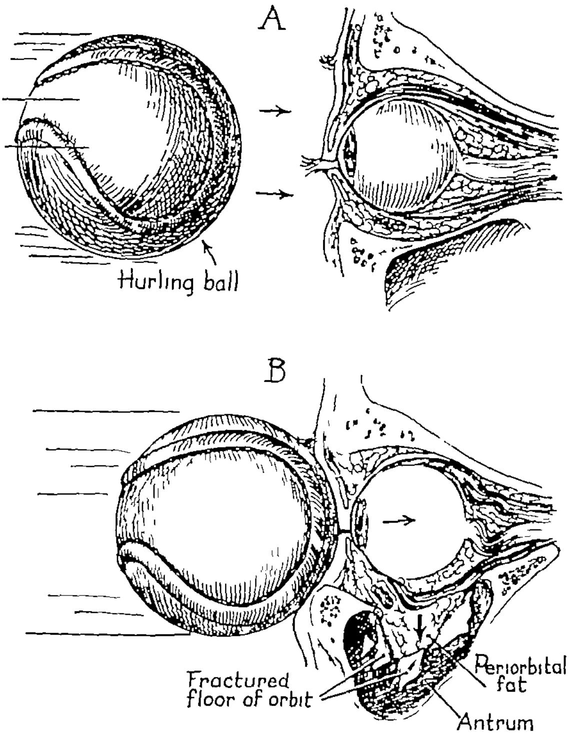


FIG. 285. External pressure forcing a blow-out fracture of the orbital floor with incarceration of the inferior oblique and inferior rectus.
(B. Smith and W. F. Regan, Jr. Am. J. Ophth. 44: 733, 1957)

Traumatic Enophthalmos

Enophthalmos appears insidiously, usually after the subsidence of the edema, hematoma and inflammatory reaction which accompany the fracture. The eyeball sinks inward progressively. Once established enophthalmos is difficult to correct because of atrophy and shortening of the intraorbital structures, thus resulting in deformity.

Various explanations have been offered for the development of traumatic enoph

thalmos. Because of this fact, an understanding of the mechanism of production is important.

Lower animal forms possess an orbital muscle which spans the floor of the orbit covering the inferior orbital fissure; this muscle protrudes the eyeball for purposes of focusing vision. In man a vestige of this muscle is also designated as the orbitalis muscle. Some anatomists discount its importance; others claim that the paralysis of this muscle is a factor in the production of enophthalmos in conditions such as Horner's syndrome which is due to paralysis of the third cranial nerve. Others feel that atrophic changes in the orbital fat due to injury of the sympathetic innervation may be responsible for the production of enophthalmos. Still other factors have been held responsible for traumatic enophthalmos: dislocation of the trochlea of the superior oblique muscle, cicatricial contraction of retrobulbar tissue and rupture of the orbital ligaments or fascial bands.

Mechanical factors appear to play an important role in orbital fractures; among these are the escape of fat into the maxillary sinus or the enlargement of the orbital cavity due to the displacement by fracture of the orbital walls (Lang, 1899). Lang contended that a fracture occurred in every case of enophthalmos and stated: "I suggest that the injury may have produced a fracture and a depression of a portion of the orbital wall; the orbital fat would then be no longer sufficient in quantity to fill this enlarged postocular area without a sinking in of the globe from atmospheric pressure and a resulting limitation in ocular movements."

Pfeiffer (1941) reviewed one hundred and twenty cases of fractures of the bones of the face with orbital involvement and found that enophthalmos was present or had developed subsequent to injury in fifty three of these cases. Fracture of the orbit was noted in every case of traumatic enophthalmos. Orbital fracture was obvious in many cases but in others, the fracture was internal or deep in the orbit unassociated with solution of continuity or deformity of the margins of the orbit, and was detected only through roentgenograms. The backward displacement of the ocular globe was as much as 9 mm. in some cases; in the majority of cases, however, the posterior displacement was 3 or 4 mm. The displacement of the eye would have been overlooked clinically in a number of Pfeiffer's cases if exophthalmometry had not been employed following radiological findings of fracture.

The radiographic findings were characteristic. The floor of the orbit was broken through into the maxillary sinus in every instance. Fragments were frequently seen in the maxillary sinus and increased density was demonstrable due to the presence of orbital tissue. The maxillary sinus was filled with orbital tissue in severe enophthalmos.

It is our belief that traumatic enophthalmos is due to escape of orbital fat into the maxillary sinus or to enlargement of the orbital cavity; the orbital fat distributed in a larger cavity no longer suffices to maintain the normal protrusion of the eyeball. Fig. 286 illustrates one of the mechanisms by which this type of enophthalmos is produced.

In "blow-out" fractures the orbital contents are held backward by scar tissue or by herniation and incarceration of orbital tissues between the depressed bony fragments.

Determination of the degree of enophthalmos is based upon the relative position of a line projected from the lateral orbital margin to the profile of the zenith of the cornea. When there is loss of bone and osseous malposition, fixed points on the affected and unaffected sides cannot be used in diagnosis. In such cases, the degree of ocular protrusion or recession is determined by the difference in the number of millimeters required to focus an instrument on each cornea with the patient's

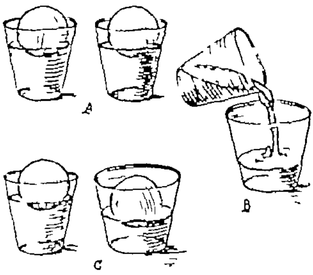


FIG 286. Diagrammatic representation of one of the mechanisms of production of enophthalmos en largement of the orbital cavity

A. The glass represents the orbital cavity the water the orbital fat and the ping-pong ball the globe. An equal amount of water in each glass maintains the balls at the same level.

B. Water is poured from one glass into a glass of larger size.

C. The ball in the larger glass is at a lower level although the amount of water is equal to that in the smaller glass. Thus, the eyeball becomes enophthal mic not only when fat escapes from the orbit but also when the orbital fat is in an orbital cavity enlarged by fracture.

head and the focusing instrument placed in a central position. This measurement may be calculated with a corneal microscope and head rest or by means of an adapted keratometer The calibration of either instrument for use as an exophthalmometer is not a difficult procedure.

The reverse mechanism diminution of the size of the orbital cavity by backwardly displaced overlapping fragments, accounts for *traumatic exophthalmos an apparently* anomalous condition occasionally seen following fractures. Orbital hematoma is another cause of traumatic exophthalmos. True exophthalmos must be *differentiated* from *pseudo-exophthalmos* due to backward displacement of the orbital rim Increase in the vertical width of the affected interpalpebral fissure may afford a false impression of exophthalmos

Traumatic Diplopia

Diplopia occurs in comminuted fractures of the orbital floor with downward displacement because the visual axis of the affected eyeball is not in alignment with that of the opposite eye.

In fragmented fracture of the thin portion of the floor of the orbit the peri-orbita are pinched between sharp comminuted bone fragments or incarcerated in a defect of the orbital floor Injury and interference of the function of the inferior rectus muscle *appears to be a principal cause of diplopia* in such cases, because of imbalanced function of the extra-ocular musculature

Diplopia is obvious immediately after injury in gross downward displacement of the orbital contents. In other cases its onset is as insidious as that of enophthalmos, becoming manifest only after the subsidence of edema and resorption of hematoma. The eyeball is displaced downward the superior palpebral groove is accentuated and upward rotation of the eyeball is either difficult or impossible.

The pattern of diplopia in orbital floor fracture is variable since it is proportional to the degree of intra-orbital tissue damage and displacement The typical severe fracture is usually accompanied by a restriction of both the depression and elevation of the ocular globe Edema and ecchymosis within the muscle cone account in part for the limitation of motility Observations have led us to the conclusion that limitation of elevation and depression is due mainly to fixation of the tissues enveloping the inferior rectus and inferior oblique muscle sheaths by *incarceration and herniation* between the bone fragments. Disturbance of the inferior oblique muscle is less evident than that of the inferior rectus because the sheath *involvement is so much closer to the* point of origin of the muscle The origin of the inferior oblique muscle is in proximity to the upper orifice of the nasolacrimal canal and is protected by the strong frontal process of the maxilla Cover uncover and

commitance tests could lead to the erroneous conclusion that involvement of the superior rectus muscle accounts for elevation limitation. The fixation of the inferior rectus muscle is demonstrated by the forced duction test by applying traction with forceps to the inferior rectus tendon Rectifying this pathology by surgical means has alleviated the oculorotary disturbance and diplopia without the need for surgery of the superior rectus muscle.

Early Preventive Treatment

A comminuted fracture involving the floor of the orbit (Fig 287*A*) with or without diplopia requires positive surgical measures if enophthalmos and diplopia are to be prevented and relieved

The diagnosis of orbital floor fracture can be made by two methods

(1) Radiological examination in the Waters view and laminograms demonstrate the depressed weak portion of the orbital floor The laminogram may reveal the fracture when the roentgenogram in the Waters position fails to show signs of fracture (Fig 288) This finding may occur in the blow-out type of fracture with an intact orbital rim. The blow-out fracture may extend through the thin portion of the orbital floor with extrusion of orbital contents into the maxillary sinus, in the absence of a fracture of the body of the zygoma The history of Case 2 illustrates such a "hidden fracture" of the orbital floor In another case diplopia and inability to rotate the ocular globe upward appeared in a 10-year-old child immediately after a first blow over the orbital area. Exploration of the maxillary sinus revealed the presence of orbital fat extruding through an opening in the "weak area" of the orbital floor

(2) Direct inspection and palpation of the orbital floor through the maxillary sinus will enable the detection of a fracture.

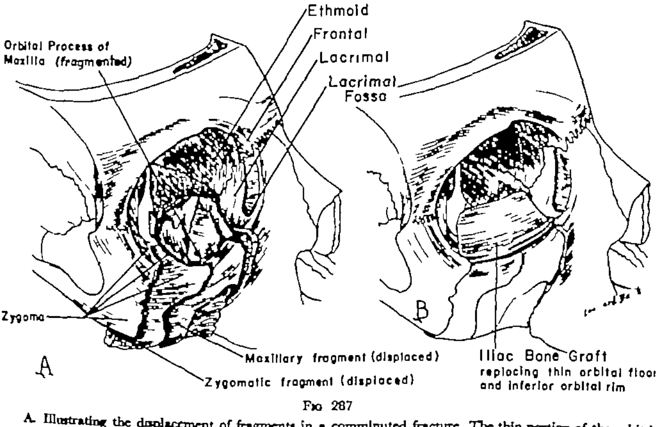


FIG 287

A. Illustrating the displacement of fragments in a comminuted fracture. The thin portion of the orbit is finely comminuted and depressed into the maxillary sinus.

B. Shows manner in which a bone graft restores the orbital floor by bridging across the comminuted area.

FIG 288. Radiological diagnosis of "blow-out" fracture. Laminogram shows a "blow-out" fracture of the weak portion of the floor of the orbit with extrusion of the orbital contents into the maxillary sinus, a view not seen in the average roentgenogram.

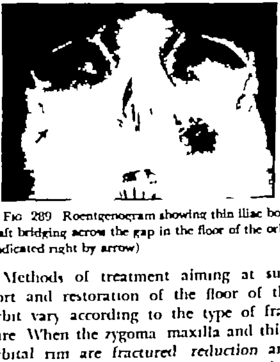


FIG 289 Roentgenogram showing thin iliac bone graft bridging across the gap in the floor of the orbit (indicated right by arrow)

Methods of treatment aiming at support and restoration of the floor of the orbit vary according to the type of fracture When the zygoma maxilla and thick orbital rim are *fractured reduction* and fixation of these bones must be provided

Investigation of the floor of the orbit through the maxillary sinus reveals whether the orbital floor is sagging or orbital fat is *escaping* through an opening in the floor with incarceration of the orbital contents into the bony window the orbital contents are depressed into and fill the *maxillary* sinus in extreme cases.

In all fractures of the zygoma and maxilla involving the floor of the orbit with diplopia whether simple or comminuted an opening is established into the maxillary sinus through a window in the canine fossa in order to inspect and palpate the orbital floor

When the orbital floor is depressed without escape of orbital fat, packing the maxillary sinus may provide adequate support until the bone fragments become consolidated When the orbital contents are extruded *through the floor and orbital fat* is seen in the maxillary sinus, a more satisfactory exposure is obtained by an incision through the skin of the lower eyelid, orbicularis oculi muscle and periosteum of the orbital rim Subperiosteal elevation of the orbital contents permits inspection of the fractured orbital floor

The herniated orbital contents are *pushed up through the orbital floor opening* and held in the orbit by means of a retractor until the gap in the floor of the orbit is closed. It is difficult to prevent the orbital fat from being again extruded into the maxillary sinus without this dual approach The continuity of the orbital floor must then be re-established a procedure which is best accomplished by an autog*enous bone graft from the inner aspect* of the ilium This thin bone graft effectively bridges the gap in the floor of the orbit and closes the communication between the orbit and the maxillary sinus (Figs. 287B 289)

The following case histories are included to illustrate the early surgical measures employed to prevent traumatic enophthalmos *and diplopia in fractures of the zygoma* involving the orbital floor

CASE HISTORIES

Case I

A 21 year-old white male suffered a fracture of the right floor of the orbit and

right frontal process of the maxilla in an automobile accident. The patient appeared to have hit some protruding object on the dashboard or the column of the steering wheel

Clinical examination ten days after the accident, revealed marked swelling and ecchymosis in the right peri-orbital region with subconjunctival hemorrhage of the right eye which was at a lower level than the left the patient complained of diplopia (Fig 290) Palpation revealed obvious disorganization of the orbital floor by comminuted fracture and fracture with slight medial displacement of the right frontal process of the maxilla Tenderness and mobility could be felt by palpation The nasal cavities had been packed because of repeated nasal hemorrhage.

Roentgenographic examination revealed (1) comminuted fracture of the right maxilla involving the floor of the right orbit and roof of the right maxillary sinus with depression of the orbital floor (2) fracture lines in the frontal process of the right maxilla and (3) fracture of the right nasal bone.

An incision approximately 6 cm. in length was made through the mucosa on the labial aspect of the right buccal sulcus the mucosa was raised from the orbicularis oris muscle by sharp dissection The periosteum was then incised and the anterior aspect of the body of the maxilla was exposed by subperiosteal elevation which was continued around the infra-orbital nerve and vessels. A transverse fracture line approximately 2.5 cm. long was observed immediately below the level of the infra orbital foramen The ends of this transverse fracture line joined with vertical fracture lines extending upward to the orbital floor delimiting a fragment which had been depressed downward for a distance of more than 1 cm. The anterior wall of the maxillary sinus below this fragment was splintered and other fracture lines extended medially into the frontal process of the maxilla

A window was established in the maxil

Fig 290

A. Appearance of patient seven days after comminuted fracture of the right floor of the orbit. Note the downward displacement of the right eye. Nasal packing for the control of hemorrhage is seen protruding from the nostrils.

B. Postoperative appearance. Both eyes are on the same horizontal plane. Note absence of enophthalmos of the right eye.

(J M. Converse & B. Smith, Brit. J Plastic Surg 9 265 1957)

lary sinus through the canine fossa The interior of the maxillary sinus was filled with blood clots and serum. The floor of the orbit was examined from below and a dehiscence was noted through which the *orbital contents protruded downward*

A 3 cm incision was made through one of the natural skin folds of the lower lid. The skin of the lower lid was raised from the orbicularis oculi muscle fibers over a distance of approximately 3 mm. Another incision through the muscle parallel to the direction of the fibers, exposed the rim of the depressed orbital floor The periosteum along the rim of the orbital floor was incised and the orbital contents were raised from the floor by subperiosteal elevation. The bone was not fractured laterally or medially and elevation of the *periosteum was not a difficult procedure.* In the central portion of the orbital floor the rim and a portion of the floor approximately 2.5 cm was depressed downward for a distance of over 1 cm Posterior to this depressed fragment was an area of comminuted thin bone through which the orbital contents were depressed into the maxillary sinus. The orbital contents were separated from the membranous lining of the maxillary sinus by careful dissection the mucous membrane had been torn in two areas, creating a direct communication between the orbital cavity and the sinus The orbital contents were now entirely free and could be raised from the floor by means of a retractor

Previous to freeing the orbital contents from the fractured orbital floor attempts *to rotate the eyeball upward* with the aid of a forceps applied to the inferior rectus tendon showed limitation of upward ocular rotation The eyeball could be rotated upward after freeing the orbital contents from the floor *This improvement was attributed* to release of the periorbita and inferior rectus muscle from attachments and fixation to the depressed comminuted fragments

The condition could be corrected either *by replacing the depressed rim fragment* and immobilizing it by means of interosseous wiring or by leaving it in its depressed position and restoring the rim and the remaining deficient portion of the floor by means of a bone graft the latter course was followed

Bone grafts were removed from the right ilium after subperiosteal exposure of the inner bony table One fragment comprising the inner table and a small amount of cancellous bone was used to bridge across the defect. Additional small fragments of cancellous bone were employed to fill the defect between the depressed fragment and the bridging bone graft Examination of both eyes showed that the right eye was now raised to a level comparable with that of the left eye. The normal contour of the *supratarsal sulcus was restored*

The edges of the skin incision in the lower eyelid were closed with interrupted fine dermalon sutures. A horizontal mattress suture was placed between the margins of the upper and lower lids to prevent opening the eye under the pressure dressing The intra-oral wound was closed with interrupted plain catgut sutures. A pressure dressing applied over the orbital area and entire right side of the face was retained for a period of five days. Antibiotic therapy was instituted

The pressure dressing and the eyelid sutures were removed after five days. Recovery was uneventful binocular vision had been restored (Fig 290)

PREOPERATIVE AND POSTOPERATIVE EYE MUSCLE STUDIES*

In the case described above diplopia was present in all fields and directions of gaze The vertical deviation at near and distant ranges in the primary position was ten diopters of right hypertropia this increased to forty diopters in the *lower*

* These studies were undertaken by Dr Byron Smith Dr H W Brown and Mrs F Knatcher in the Eye Muscle Clinic at the Manhattan Eye Ear and Throat Hospital

right field. The right hypertropia amounted to thirty diopters in the lower left field of gaze. There was a left hypertropia of eighteen diopters in the gaze upward and to the right.

At the first dressing five days after surgery diplopia in the primary position both at near and distant ranges had disappeared completely The field of binocular single vision gradually assumed normal proportions during the first month of postoperative observation. Six weeks following surgery a small residual left hyperphoria could be demonstrated by cover test in the extreme gaze upward and to the left and upward and to the right The residual phoria was so small that the fusional tendency overcame the diplopia during all normal visual activity The fusional amplitude was excellent in the lower fields of gaze where most visual activity occurs Distant vision was normal and comfortable

EXOPHTHALMOMETER OBSERVATIONS.

The preoperative exophthalmometer reading of each eye was 16 mm As previously mentioned edema and ecchymosis within the tissues surrounding the injured eye tend to mask enophthalmos which is usually observed as a late finding The final exophthalmometer reading six weeks postoperatively revealed an enophthalmos of only 1 mm in the injured eye. Had treatment not been instituted early it is logical to predict that a serious enophthalmos and permanent diplopia would have occurred.

Case 2

A 29-year-old white male was struck in the right eye by a batted hurling ball two hours prior to admission (Fig 285)

Positive findings on physical examination were limited to the orbital area and the eye. The patient showed severe swelling of the right upper and lower lids and marked subconjunctival edema and hemorrhage There was no abrasion of the cornea The pupil on the right reacted sluggishly to light Elevation of the right eye was limited in all fields of upward gaze. Diplopia was present in all right fields and in the primary position A small hyphema was observed at the base of the anterior chamber Fundoscopic examination was difficult because of hazy vitreous Edema surrounding the macula was pale in comparison with peripheral retina. Vision in the right eye was 20/100 and 20/20 in the left eye. Tonometric tension registered 40 mm Hg in the right eye and 20 mm. Hg in the left eye. A small horizontal laceration of the skin extended downward near the mid point of the lower orbital margin There was no irregularity in the bony contour of the orbital margin or the surface of the zygoma Exophthalmometry disclosed no evidence of ocular displacement.

X rays of the right orbit, skull and nose showed no demonstrable fracture of the nasal bones An increase of soft tissue density in the right orbit and a small amount of emphysema in the upper aspect of the right orbit were apparent. There was a depressed fracture of the floor of the right orbit, one fragment being depressed about 10 mm. The left and right optic foramina showed normal configuration. The cranial vault and sella turcica were normal Sinus films showed moderate clouding of the right ethmoids and right maxillary sinus

Measurements five days later demonstrated that exotropia secondary to limitation in the right ocular elevation was responsible for constant diplopia. Double vision was present in all fields of gaze

Secondary infection in the laceration and edema had sufficiently subsided in an additional five days to permit surgical exploration and treatment. The following procedure was performed under general anesthesia

A skin incision 2.5 cm. in length and parallel to the right lower orbital margin was extended through the skin subcutaneous tissues and periosteum and dissection was continued posteriorly until a de

fect in the orbital floor measuring 15 by 25 mm. was exposed. The anterior margin of the bony defect was located about 6 mm. within the lower orbital margin Many thin fragments of bone and the lower orbital contents were displaced into the maxillary sinus. A Caldwell Luc approach to the maxillary sinus was made through the right canine fossa Degenerated fat globules floated out as the hematoma within the antrum was evacuated A rent in the mucous membrane of the roof of the sinus was demonstrated. A graft of cortical bone 3 to 4 mm. in thickness was removed from the internal surface of the right ilium and shaped to fit over the orbital floor defect. The incision was closed with fine dermalon sutures, and the Caldwell Luc mucous membrane incision was sutured with catgut. An interpalpebral suture was placed to prevent opening of the right eye under the pressure dressing Antibiotic therapy was instituted.

The postoperative course was uneventful The pressure dressing was removed in four days. Roentgenographic examination four weeks later showed the bone graft in correct position Residual clouding of the right sinus was present. The diplopia had disappeared at the first postoperative dressing The muscle balance was within normal limits and exophthalmometer measurements were recorded as equal on both sides.

This case demonstrates a typical "blowout" fracture in the absence of signs of zygomatic fracture, requiring restoration of the continuity of the orbital floor in order to prevent functional disturbance of the eyeball

Late Complications

Most complications are the result of malunited fracture The resulting deformity may be slight or quite marked The correction of the deformity resulting from malunited fracture may require osteotomy and replacement of the zygoma or contour restoration by bone grafts. More serious functional disturbances, however result from malunited fractures and to a large extent dictate the type of treatment.

In fracture-dislocations of the zygoma which result in contour deformity without separation of the frontozygomatic junction or ocular disturbances, and without interference with the normal excursion of the lower jaw contour restoration by a bone graft is the simplest method of treatment in preference to osteotomy and replacement of the bone (see Fig 616 Chapter 21) Radiating fracture lines extending backward into the optic canal with consequent danger of blindness are a reminder that prudence should be exerted in attempting osteotomy

In malunited fracture-dislocations of the zygoma with separation at the frontozygomatic junction and also in fractures with downward displacement of the floor of the orbit, in addition to contour restoration by bone grafts, reconstruction of the floor of the orbit by bone grafts is indicated (see Chapter 21)

The treatment of traumatic enophthalmos is preventive Late treatment of enophthalmos is difficult some degree of improvement can be obtained by reconstructive measures (see Chapter 21)

In malunited fractures of the zygomatic *arch with impingement upon the coronoid* process of the mandible either by the body of the bone or the zygomatic arch, osteotomy and elevation of the depressed zygoma alleviates the condition When elevation of the zygomatic structures is not possible or when new bone formation restricts the space within the zygomatic arch the resection of the coronoid process through in intra-oral approach is required to permit mandibular movement.

Persistent anesthesia in the area of dis-

tribution of the infra-orbital nerve may require exploration to locate the mal united fragment of bone causing com pression of the nerve Restoration of nerve function and relief of anesthesia follows resection of the fragment. Permanent anesthesia of the infra-orbital nerve is a rare condition Adhesions between the eyeball and the lateral orbital wall may prevent normal rotation of the ocular globe.

10

FRACTURES OF THE BONES OF THE FRONTO-ETHMOIDAL REGION* TRAUMATIC CEREBROSPINAL RHINORRHEA

This chapter offers a rational approach to the diagnosis and treatment of fractures of the bones of the fronto-ethmoidal region in particular those complicated by cerebrospinal rhinorrhea.

Severe injuries of the middle third of the face with concomitant fractures of the maxilla and nasal bones may be associated with fractures of the frontal bone or the bones of the interorbital space (Fig 291)

Maxillary fractures may result in upward and backward displacement of the bone The central portion of the maxilla which encloses the maxillary sinus, fractures easily and can absorb a severe traumatic force. The frontal process of the maxilla however may be displaced bodily upward and backward into the interorbital space. Blows on the chin occasionally result in fracture of the base of the skull

The bones of the middle third of the face are related one to another through the ethmoidal and frontal sinuses and to the cribriform plate and frontal lobes of the brain which may also be injured

ANATOMICAL CONSIDERATIONS

The Frontal Bone

The frontal bone is shell like in shape and consists of a vertical portion corresponding with the region of the forehead and a horizontal portion which forms the roof of the orbital and nasal cavities (Fig 292).

The vertical portion is composed of an external or anterior surface and an internal or posterior surface which is applied to the frontal lobe The two frontal eminences are located on the external surface on either side of the mid line suture. Below the frontal eminences are two arched elevations, the superciliary arches. These lateral prominences are joined medially by a smooth elevation the glabella The curved supra orbital margin sharp and prominent lies beneath each superciliary arch The supra orbital notch which transmits the supra orbital vessels and nerves, is located at the junction of its medial and intermediate third. Laterally the frontal bone is joined to the zygoma by its zygomatic process.

Between the supraorbital margins a portion of the frontal bone projects downward to join the nasal bones. The nasal process projects downward and forward beneath the nasal bones and frontal processes of the maxilla thus supporting the bridge of the nose

The horizontal portion of the frontal bone consists of two thin triangular-shaped orbital plates these form the vaults of the orbits and are separated from one another in the mid line by the ethmoidal notch a median gap which is quadrilateral in shape

* Written in collaboration with Edgar A. Kahn M.D and Richard C Schneider M.D from the Department of Surgery Section of Neurosurgery University of Michigan Medical School

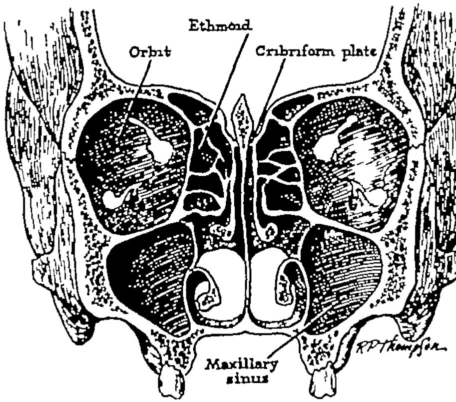


FIG 291 The interorbital space

and filled by the cribriform plate of the ethmoid.

The Frontal Sinus

The size of the frontal sinus varies greatly from that of an ethmoidal cell to one of very large size pneumatizing the frontal bone. Occasionally it is absent.

The sinus has the shape of a pyramid with inferior anterior and posterior walls (Figs. 291 293) The inferior wall or floor of the frontal sinus corresponds to the roof of the orbit thus is the thinnest wall of the frontal sinus. The anterior wall is thickest and is composed of cancellous bone. The posterior wall is thinner than the anterior wall and is composed entirely of compact bone which separates it from the frontal lobe.

The Interorbital Space

The term interorbital space designates an area between the orbits beneath the floor of the anterior fossa of the skull (Fig 291) The interorbital space is essentially constituted by the two ethmoidal labyrinths,

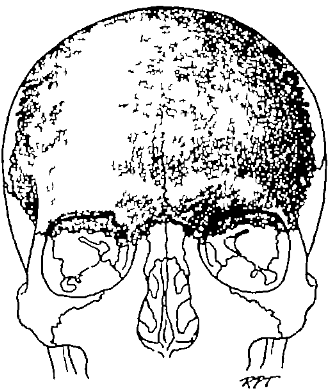


FIG 292. Drawing showing relationships of the frontal bone to the bones of the middle portion of the face.

one on each side. Each lateral ethmoidal mass projects a few millimeters higher than the cribriform plate which separates it from the opposite ethmoidal labyrinth

10

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The vertical portion is composed of an external or anterior surface and an internal or posterior surface which is applied to the frontal lobe. The two frontal eminences are located on the external surface, on either side of the mid line suture Below the frontal eminences are two arched elevations, the supraciliary arches. These lateral prominences are joined medially by a smooth elevation the glabella. The curved supraorbital margin sharp and prominent, lies beneath each superciliary arch. The supraorbital notch which transmits the supraorbital vessels and nerves, is located at the junction of its medial and intermediate third Laterally the frontal bone is joined to the zygoma by its zygomatic process.

Between the supraorbital margins a portion of the frontal bone projects downward to join the nasal bones. The nasal process projects downward and forward beneath the nasal bones and frontal processes of the maxilla thus supporting the bridge of the nose

The horizontal portion of the frontal bone consists of two thin triangular-shaped *orbital plates* these form the vaults of the orbits and are separated from one another in the mid line by the ethmoidal notch, a median gap which is quadrilateral in shape

* Written in collaboration with Edgar A. Kahn M.D and Richard C. Schneider M.D from the Department of Surgery Section of Neurosurgery University of Michigan Medical School

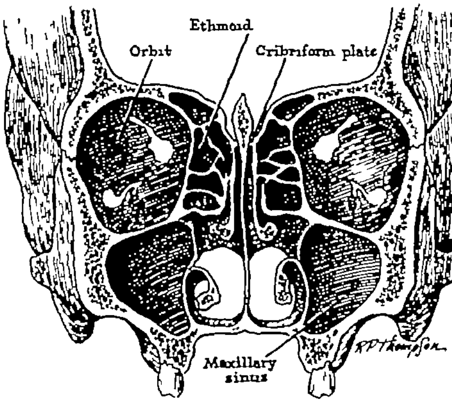


Fig 291 The interorbital space

and filled by the cribriform plate of the ethmoid

The Frontal Sinus

The size of the frontal sinus varies greatly from that of an ethmoidal cell to one of very large size, pneumatizing the frontal bone. Occasionally it is absent.

The sinus has the shape of a pyramid with inferior anterior and posterior walls (Figs. 291 293) The inferior wall or floor of the frontal sinus corresponds to the roof of the orbit this is the thinnest wall of the frontal sinus. The anterior wall is thickest and is composed of cancellous bone The posterior wall is thinner than the anterior wall and is composed entirely of compact bone which separates it from the frontal lobe.

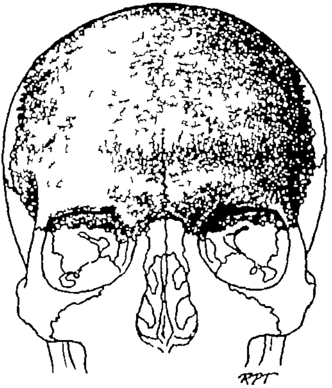


Fig 292. Drawing showing relationships of the frontal bone to the bones of the middle portion of the face.

The Interorbital Space

The term interorbital space designates an area between the orbits, beneath the floor of the anterior fossa of the skull (Fig 291) The interorbital space is essentially constituted by the two ethmoidal labyrinths, one on each side. Each lateral ethmoidal mass projects a few millimeters higher than the cribriform plate which separates it from the opposite ethmoidal labyrinth.

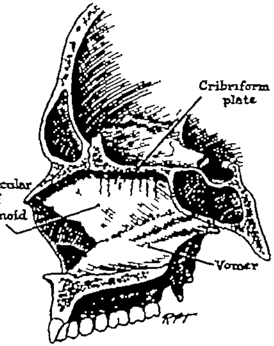


FIG. 293 Drawing of sagittal section of a fragment of the skull lateral to the nasal septum. The relationship of the perpendicular plate of the ethmoid to the cribriform plate is shown.

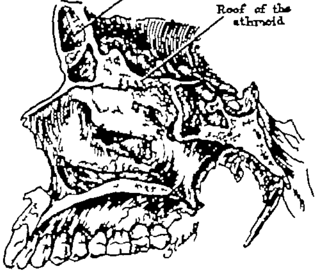


FIG 294 Drawing showing the lateral wall of the nose, the septum having been removed, and also the relationships of the frontal and ethmoidal sinuses with the anterior cranial fossa.

The interorbital space is roughly cuboidal in shape being wider in front than posteriorly It is limited above by the cribriform plate in the mid line, and by the roof of each ethmoidal mass on the sides, and is divided into two approximately equal halves by the nasal septum. The interorbital space is limited below at the level of a horizontal line through the lower border of the ethmoidal labyrinth. Laterally it is constituted by the medial walls of the orbit formed by the lacrimal bone and the os planum (lamina papyracea) of the ethmoid and is closed posteriorly by the anterior wall of the body of the sphenoid. Anteriorly the interorbital space is limited by the frontal process of the maxilla in front of which are the nasal bones, and by the internal angular process of the frontal bone.

The Ethmoidal Sinus

The ethmoid occupies the upper half of the lateral wall of the nose the lower half is flanked by the maxillary sinus (Fig 291) Each lateral mass of the ethmoid projects about one-quarter of a centimeter above the cribriform plate. The ethmoid is pyramidal or cuboidal in shape measuring 3.5 to 5 cm. in length 1 5 to 2.5 in width. It is cellular in structure and contains 8 to 10 cells with thin lamellar walls these cells drain into the middle meatus of the nose. The frontal sinus drains through the ethmoid either through a distinct duct or empties into an anterior ethmoidal cell and into the middle meatus (Fig 291) There is thus an intimate anatomical relationship with the frontal sinus through the frontonasal duct. It will be recalled that, in embryological development the frontal sinus is formed by an outcropping ethmoidal cell

Fractures with Cerebro-spinal Rhinorrhea

The telescoping type of crash injury with deformity due to frontal maxillary and nasal fractures, is the type of injury to the floor of the anterior fossa with cerebrospinal rhinorrhea encountered most frequently by the plastic surgeon Penetrating fragments of bone or radiating fracture lines cause lesions of the ethmoid and cribriform plate with associated tearing of the dura mater and arachnoid (Fig 295) The pointed crista galli when fractured may

penetrate the dura Zygomatic fractures with marked displacement and with fracture lines extending backward and medially across the orbit to the ethmoid or the orbital floor of the frontal sinus may tear the dura mater resulting in cerebrospinal rhinorrhea

FIG 295 Schematic drawing illustrating anatomic disruption of the frontoethmoidal region and the possibility of frontal lobe injury in such cases.

SURGICAL PATHOLOGY

Injury to the dura mater and arachnoid resulting in cerebrospinal rhinorrhea may occur in three different ways (Cairns, 1937)

1 Depressed fractures of the frontal sinus, involving the posterior wall may cause tearing of the dura mater and penetration of comminuted bone fragments into the frontal lobe with a varying amount of brain damage. A fracture line may extend inward to the region of the cribriform plate.

2. The nasal bones and frontal processes of the maxilla are pushed back over the lacrimal bones into the ethmoidal labyrinth in pyramidal fractures of the maxilla (Lefort II) with penetration into the interorbital space, these injuries are usually the result of a head-on crash accident (Fig 296) Fracture lines may penetrate into the roof of the ethmoid situated laterally in the interorbital space and bone fragments, con

FIG 296

(*Left*) Photograph of patient taken five days after injury showing elongation of the middle portion of the face.

(*Right*) Note subconjunctival hemorrhage, flattening of the nose and loss of dental occlusion.

sisting of sharp-edged ethmoidal cell walls may penetrate the dura mater The cribriform plate situated medially may be involved by direct extension of the fracture lines, or by the telescoping of the perpendicular plate of the ethmoid. The dura *mater is much thinner in the region of the* cribriform plate than in the frontal region it constitutes the inner periosteum of the bone in this area and is readily penetrated or torn. Cerebrospinal rhinorrhea may also be caused by the tearing of dural prolongations along the olfactory nerves passing through the cribriform orifices.

3 In high maxillary fractures with craniofacial dysjunction (LeFort III) in which the middle third of the face is detached from the skull and pushed upward and backward, cerebrospinal rhinorrhea is produced by the same mechanism of impaction and comminution of the interorbital space.

Cerebrospinal rhinorrhea may follow any type of fracture which involves the paranasal sinuses, including the sphenoid sinuses, varying from the finest fracture line, barely visible on roentgenograms to extensive comminution and depression of the fronto-ethmoidal area of the face

EXAMINATION AND DIAGNOSIS
Clinical Examination

The patient may be unconscious, or have had a loss of consciousness of long or short duration Loss of consciousness often signifies brain injury The patient may be irritable restless or even thrashing about in severe injuries. As in other fractures around the orbit marked swelling about the eyes occurs with ecchymosis of the lids and subconjunctival hemorrhage in the orbit. The swelling may be accompanied by marked mechanical limitation of eyeball movements. Anesthesia in the supra or infra orbital regions results from injury to the nerve branches in these areas.

There may be little evidence of deformity because of hematoma or swelling In some cases the deformity is evident when the frontal bone has been crushed in or the nasal structures are markedly pushed backward. The bones may be loose and crepitation may be felt when they are mobilized. The entire upper jaw may be movable and motion may be felt in the bones of the interorbital space A portion of the forehead skin *may be avulsed in compound fractures*, exposing the frontal bone and revealing the site of fracture

Clear fluid escaping from the nose indicates cerebrospinal rhinorrhea Patients with cerebrospinal rhinorrhea show an initial escape of blood the fluid then becomes brownish in color and finally clear This fluid is sometimes seen to pulsate within the nose. Sneezing is frequent and the patient experiences a postnasal drip with a salty taste. A practical test to confirm a cerebrospinal rhinorrhea is to effectuate a bilateral jugular compression or to lower the patient's head over the side of the bed a sudden increase in the escape of the clear fluid may be noted The fluid may soak the bed linen at night without stiffening it.

It is usually possible to collect a sufficient amount of fluid for a chemical test It is found to be free from mucin and to contain sugar nasal secretions contain mucin but no sugar The chemical test may therefore be considered as indicative of spinal fluid. Other diagnostic tests have been employed, such as the injection of a dye into the lumbar theca or ventricle and then observing its escape from the nose These dye injection tests, however are not practical as dye injected into the lumbar theca may be absorbed into the blood stream. Injection of dye into the ventricle usually requires a separate trephine opening in the skull

The rhinorrhea may be from one or both nostrils. A unilateral rhinorrhea usually indicates the side of the dural tear but this sign is not always reliable It may be presumed that if the fracture and the rhinorrhea are on the same side the dural tear will be limited to that side also A bilateral rhinorrhea usually requires a bilateral exploration although it does not necessarily signify that bilateral dural tears are present

Some neurosurgeons feel that bilateral exploration is always required for better exposure (Adson and Uihlein 1949)

Anosmia is helpful in diagnosing the likely site of the dural tear in cases of rhinorrhea (Lewin 1954) The presence of anosmia usually indicates that the dural tear is in the region of the ethmoidal roof or cribriform plate. If anosmia is not present, the rhinorrhea is probably the result of a tear situated more laterally behind the frontal sinus

Roentgenographic Examination

Stereoscopic roentgenograms and laminograms are required to estimate the amount of the damage for fractures of the cribriform plate may be impossible to detect by ordinary radiographic examination The presence of air in the subdural subarachnoid space or in the ventricle is a sign of communication with the nasal cavity or sinuses establishing a direct pathway to infection and is an absolute indication for operation. Air may not be detected during the first twenty four hours. Roentgenograms should therefore be repeated if the patient shows increasing signs of frontal lobe dysfunction in the nature of mental changes.

Fragmentation and a buckled appearance of the cribriform plate suggest the possibility of penetration of fragments of ethmoidal cells into the brain (Fig 297) this is a further indication for operation Laminograms may be of help in evaluating the location of the damage and the degree of displacement of the fragments.

TREATMENT OF CEREBROSPINAL RHINORRHEA

Surgical versus Conservative Treatment

Surgical repair of cerebrospinal rhinorrhea was a hazardous and formidable procedure previous to the days of chemotherapy Taylor (1934) quoted a mortality of 30 per cent following operation Cairns (1937) advocated repair through a transfrontal approach in all cases of delayed rhinorrhea and Dandy (1944) concluded that a cerebrospinal fistula should not be left open for more than two weeks Adson and Uihlein (1949) stated that cerebrospinal rhinorrhea following fractures frequently ceases spontaneously and that a period of eight weeks should elapse before deciding to operate. The necessity for repairing the dura in all cases where cerebrospinal rhinorrhea continues for several weeks is now generally accepted (Kahn Bassett, Schneider and Crosby 1955) Case 1 illustrates the dangers of undue delay in performing necessary surgery Schneider and Thompson (1957) have reported several cases of traumatic cerebrospinal rhinorrhea with recurring bouts of

FIG 297 Roentgenogram showing comminuted fracture of the fronto-ethmoidal area with penetration of a bone fragment into the frontal lobe (A) (J M. Converse Ann. Otol. Rhin. & Laryng., 52 637 1943)

meningitis fifteen years after injury The head injury responsible for the condition had been forgotten in some of these cases.

The use of antibiotics has lessened the risk of intracranial infection during the acute stages after injury and has lowered the incidence of postoperative infection Sulfadiazine has proved to be a particularly effective agent in these cases. Antibiotics have also diminished the risk of meningitis in patients with cerebrospinal rhinorrhea and therefore permit postponement of surgical interference until the surgeon is assured of the need for intervention. The technique of operation has been facilitated by the use of wide bone flaps permitting adequate exposure of the area and progress in radiology has facilitated more accurate location of the fracture sites In addition, the method of dural repair by the intradural approach developed by Eden (1942) provides a quicker and better exposure of the anterior fossa than the extradural approach of the past. It is often desirable to combine both intradural and extradural approaches, for suturing is sometimes difficult through the intradural approach alone

Patients with cerebrospinal rhinorrhea present a dual problem. The first is that of the dural tear with direct communication between the nasal cavity and the subarachnoid space and the danger of subsequent meningitis the penetration of bone fragments into the brain may result later in the formation of a brain abscess. The second is the problem presented by fractures of the bones of the middle third of the face which must be treated to avoid serious deformity and impaired masticating efficiency

The initial treatment should be conservative the patient should be treated for shock and given antibiotic therapy As soon as the patient s condition permits, an evaluation of the anatomical damage is made by roentgenograms. If the radiological examination fails to demonstrate "buckling or fragmentation of the cribriform plate or penetration of the dura mater by bone fragments, reduction of the fractured maxilla is initiated by gentle intermaxillary traction, and careful reduction of fractured fragments of the nasal bones is done. The object of slow reduction of the displaced fragments by elastic traction is to avoid increasing damage in the region of the cribriform plate by brusque manipulation

When the radiological examination fails to show evidence of damage other than a fracture line the patient is treated conservatively while being observed for signs of impending complications such as meningitis, extradural or intracerebral abscess No packing is placed in the nasal fossae smoking is forbidden and the head of the bed is elevated to an angle of 60 degrees. The patient should be warned against blowing the nose because of possible recurrence of the leakage and an aerocele or forcing additional tissue or air into the cranial cavity If the cerebrospinal rhinorrhea is prolonged over a period of several weeks, an operation to close the fistula should be considered

Surgical Repair of Cerebrospinal Rhinorrhea

An intracranial operation is a necessity if there is evidence of penetration of the dura mater by fragments of bone and should be performed soon after the patient has recovered from the immediate effects of the brain injury The operation is always rendered more difficult at this stage by the swelling of the contused brain The protection afforded by the antibiotics will tide the patient over the waiting period until the optimum time for operation has arrived.

The location of the tear in the dura mater should be determined It is usually in the area of maximum bone damage. If the cerebrospinal leakage originates from an area situated to one side of the mid-line, a unilateral approach may be used, raising a bone flap to obtain exposure of the lesion Some surgeons prefer to approach the damaged

area through a coronal incision above the hair line to dissimulate the subsequent scar raising a large size bone flap thus exposing the frontal lobe and the floor of the anterior fossa. Bleeding from the sagittal sinus is usually controlled with fibrin foam ligation of the sinus is performed safely anterior to the Rolandic area.

Comminuted fragments in the area of the frontal sinus are removed from its anterior wall The interior of the sinus is carefully inspected and lines of fracture and depression of the posterior wall are noted. Comminuted and depressed bone fragments are removed and the dura mater is exposed. If one or more tears are present they should be followed to their termination Pulped and necrotic brain tissue should be aspirated. The dural tears are carefully sutured with fine silk A transplant of fascia lata or temporal fascia may be employed if the tear in the dura is beyond repair

Fascia lata from the thigh (Cushing 1927) is well suited for covering the fistulous area The fascia may be applied extradurally and carefully sutured with interrupted sutures. The intradural approach however has a distinct advantage for the dura is thin and adherent to the crista galli and cribriform plate stripping it from the bone is a tedious and difficult procedure. In using the extradural approach, it is difficult to avoid tearing the dura mater when separating it from the bone The extradural approach sometimes necessitates the sacrifice of the olfactory nerves, with consequent loss of smell in order to obtain exposure for placing the fascial graft. This inconvenience is not encountered in the intradural approach which by contrast to the extradural alone has proved to be a simpler operative procedure in addition the fascia lata graft is readily maintained.

One advantage of the combined intra and extradural exploration is the possibility of instilling indigo dye intradurally to locate points of leakage by extradural examination of the cribriform plate region

Case Histories*

Case 1

T F 36-year-old garage mechanic, sustained a fracture to the right frontal region when he was struck by the rim of an exploding truck tire. The right frontal wound was exposed in a nearby hospital The surgeon noted a watery ooze from the right frontal fracture which apparently was linear A smear of the fluid was sent to the laboratory The wound was debrided and closed The pathology report, forty-eight hours later indicated the presence of brain tissue in the specimen

Skull roentgenograms three days after the accident, (Fig 298*A* *B*) showed a fracture of the posterior wall of the right frontal sinus with the inner table displaced to a depth of one inch into the right anterior fossa The outer table of the right frontal sinus although fractured was not depressed

The 6 cm vertical wound in the right frontal area was again debrided the incision was extended upward on the forehead to obtain adequate exposure. The outer table of the skull at the fracture site was removed a much larger area of inner table was depressed than one would anticipate from the roentgenograms There were multiple small lacerations of the dura which required debridement to form one large defect. The tip of the right frontal lobe was necrotic, hemorrhagic, and slightly purulent this required removal A fascia lata graft was then sutured into place to complete a water-tight closure of the dura The wound was closed with through and through silk sutures.

The incision healed well Postoperative roentgenograms (Fig 298*C* *D*) show the size of the bony defect, which was corrected six months later by an iliac bone graft.

Comment This case illustrates the value of good roentgenograms prior to surgery the importance of adequate debridement to

* These case histories were contributed by Dr E. A Kahn and Dr R C. Schneider

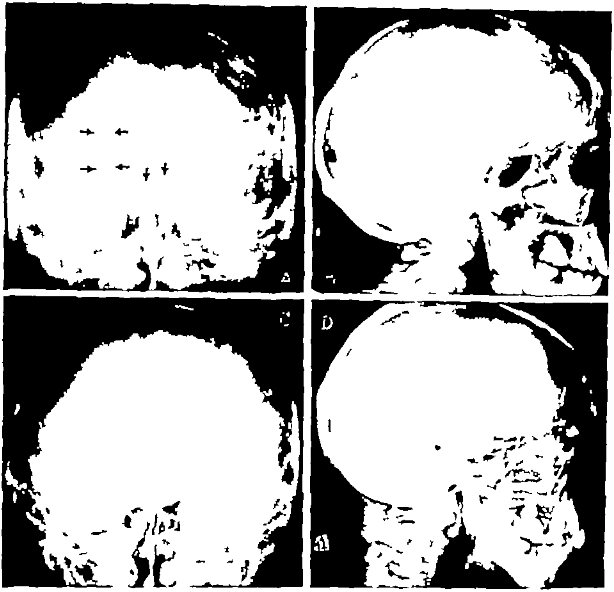


FIG 298. Case 1

A. Anterior posterior roentgenogram shows the fracture of the right frontal region
B Lateral view shows the depressed fracture of the inner table.
C. Anterior posterior roentgenogram shows the postoperative defect in the right frontal area.
D Lateral view demonstrates complete removal of the retained bone fragments.

prevent cerebral abscess and the use of a dural graft to permit water tight closure.

Case 2

D M., a 26-year-old man received multiple lacerations of the left forehead and a palpable depressed *fracture of the left frontal* bone in an automobile accident. He was semiconscious but could move all four extremities on admission Blood and cerebrospinal fluid exuded from the right ear and there were massive periorbital ecchymoses The left pupil was dilated and did not react to light and in accomodation The left hand was weaker than the right but otherwise the patient was neurologically negative

Roentgenograms demonstrated multiple *fractures of the facial bones and a severe* egg shell fracture of the skull (Fig 299) The buckled cribriform plate could be well visualized in the lateral view (Fig 299*B*) The lacerations of the left supraorbital region were debrided and sutured under

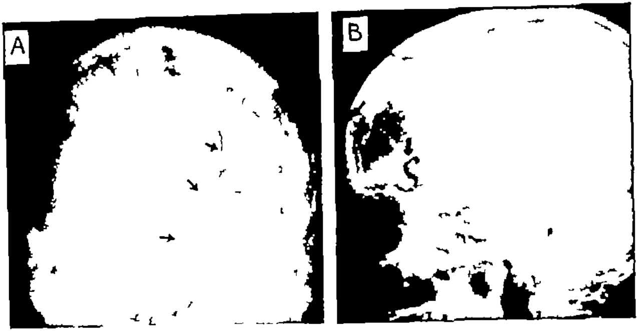


Fig 299 Case 2

A. The anterior view shows the massive "egg shell fracture of the skull.

B. The lateral view demonstrates the buckling of the cribriform plate, the fracture through the posterior wall of the frontal sinus and through the sphenoid ridge.

intratracheal anesthesia. Since exposure through this wound did not permit adequate surgical intervention a transcoronal incision was made and a large transcoronal osteoplastic flap fashioned from the fracture fragments of the skull was reflected well across the mid line but based primarily on the left temporalis muscle

The left frontal sinus and extradural space were filled with necrotic liquid brain tissue. There was a bilateral laceration of the dura across the frontal region Destroyed tissue in the anterior portion of both frontal lobes was found and debrided to normal brain. The dura was debrided and two fascia lata grafts applied, extending from the frontal sinus backward to the optic foramina. There was severe damage to the crista galli cribriform plate and frontal sphenoid and ethmoid sinuses. Loose bone fragments were removed and these sinuses were exenterated. Defects in the skull were plugged with pledgets of temporalis muscle. The various bone fragments were wired into place after making sure that the dural graft was water tight and the scalp closed with through and through sutures. Sodium sulfadiazine intravenously and massive antibiotic therapy were instituted The patient gradually regained consciousness and a postoperative picture was taken three and one half weeks after the accident (Fig 300)

Fig 300. Case 2

The patient's postoperative appearance showing the left supraorbital laceration and the transcoronal operative incision. This picture was taken twenty five days after the head injury

A year later his mental state appeared satisfactory and the neurological examination was within normal limits except for early optic atrophy

Comment This case shows the advisability of closing the original wound and then resorting to a transcoronal incision for adequate surgical exposure.

Case 3

C. W a 38-year-old iron worker fell from a roof and struck his head on a concrete floor producing a compound "egg shell" fracture of the left frontal area He was transiently unconscious vomited frequently and had continual profuse cerebrospinal fluid rhinorrhea from the left nostril The left frontal compound depressed fracture was debrided and elevated at a local hospital He was discharged and continued to have profuse cerebrospinal drainage, headache, diplopia and extreme nervousness. There had been a weight loss of thirty pounds from the time of the accident until he was seen two months later His neurological status was unchanged from that immediately following the accident.

Through a transcoronal incision a bifrontal osteoplastic craniotomy was done and bilateral fascia lata grafts were inserted to repair multiple extensive lacerations of the dura extending from the crista galli backward to the optic chiasm bilaterally There were fractures into the cribriform plate left frontal and ethmoidal sinuses and fractures of the left orbital plate. The loose bone fragments were removed and the bony defects packed with pledgets of temporalis muscle. Unfortunately the dural graft could not be sutured solidly at the level of the chiasm

The patient was confused postoperatively belligerent and noted bitemporal hemianopsia. Roentgenograms two weeks after operation demonstrated fractures and bony defects due to the previous craniotomy and a traumatic left frontal pneumocephalus (Fig 301)

The previous osteoplastic flap was elevated and intradural exploration of the anterior fossa was done. A large pneumocele in the left frontal lobe apparently arose anterior to the left optic nerve opening into the ethmoidal cells. The dural graft was intact along its entire margin except where the free edge lay posteriorly at the optic

FIG 301 Case 3

A. Anterior-posterior and

B. Lateral roentgenogram views demonstrating the left frontal traumatic pneumocephalus after the repair of the cerebrospinal fluid leak. Note the large osteoplastic bone flap which extends well across the mid line to enable section of the longitudinal sinus and falx, and permits exposure of both anterior fossae

chiasm, at which point suture had been impossible. An adhesion from the graft which was depressing the chiasm was sectioned. The bony defects in the base of the skull were plugged with additional muscle tissue and the wound was closed.

The patient was placed on sulfadiazine, penicillin and streptomycin postoperatively He was discharged with no change in his preoperative neurological deficit. The last follow-up examination two months after operation revealed a pleasant patient with bilateral anosmia and some bitemporal hemianopsia but no other complaints.

Comments This case indicates the necessity for plugging bony defects adequately with pledgets of muscle to prevent cerebrospinal fluid rhinorrhea and pneumocephalus. It also demonstrates that complete suture of the dural graft at the optic chiasm may be impossible, but if properly placed the graft may seal off the leak satisfactorily Insertion of such a graft must be performed cautiously to avoid redundant fascia lata from pressing on the optic chiasm, thus resulting in an increase in the bitemporal hemianopsia

Combined Intracranial Surgery and Reduction of Facial Fractures. The Dual Approach

In exceptional cases, with accompanying telescoping fracture of the maxilla and nasal bones, the fractured bones can be reduced by forceful traction from below During this reduction by one operator the other is able to observe the region of the cribriform plate, insuring that no sharp piece of bone is displaced which may cause penetration of the dura

When the patient's condition permits intermaxillary fixation and a removable headgear or Barton bandage are adequate means of treatment. We have observed cases of severe maxillary fractures treated with direct interosseous wiring and wire loop technique which were consolidated in malunited positions. Intermaxillary fixation should be provided to restore adequate occlusal relationships.

The serious general condition of the patient respiratory obstruction hemorrhage or unconsciousness is a contraindication for intermaxillary fixation Two courses of action may be taken in such cases (1) an elective tracheotomy or (2) intermaxillary fixation employing elastic bands, in order to provide the reduction of the maxillary fragments

Treatment of Fractures Involving the Frontal Sinus

Individuals with large frontal sinuses may show a protrusion immediately above the supraorbital arch this prominent area is susceptible to fracture Excluding the possibility of a concomitant serious head injury fracture with backward crushing of the anterior wall of the frontal sinus leaves the patient with a depression deformity if no treatment is applied

If careful clinical and radiological examination reveals intracranial injury and a posterior wall fracture of the frontal sinus a coronal incision and an osteoplastic flap should be undertaken

In uncomplicated fractures of the anterior wall of the frontal sinus an incision is made along the upper portion of the lateral wall of the nose from the point where the root of the nose joins with the supraorbital arch to a few centimeters below The incision is through the skin and periosteum equidistant between the dorsum of the nose and the inner canthus of the eye. Subperiosteal elevation is extended upward to below the supraorbital arch The lacrimal sac is temporarily elevated and retracted from the lacrimal groove Posterior to the area of the lacrimal groove the lamina papyracea of the ethmoid is cut through and the ethmoidal sinus is penetrated. Working upward from the ethmoidal sinus with a small punch it is possible to follow the ethmoidal cells until the medial aspect of the frontal sinus is reached. Part of the

floor of the frontal sinus is removed and the frontal sinus is entered. The fractured anterior wall of the frontal sinus is pried forward with a blunt probe or a hard rubber catheter If manipulation is not adequate or if comminuted fragments tend to fall back into the frontal sinus after reduction gauze packing introduced through the opening is maintained for a few days until consolidation occurs. The wound is closed if reduction is satisfactory If the packing must be retained, the wound is partly closed with the gauze packing protruding through one portion to permit later removal An alternate procedure is to close the wound completely with the gauze packing protruding into the nasal cavity In these cases it is necessary to perform an anterior ethmoidectomy remove the anterior portion of the middle turbinate and exenterate most of the ethmoidal cells located in the area below the frontal sinus. The packing is removed through the nose after a period of approximately one week for by that time sufficient consolidation of the anterior wall of the frontal sinus has occurred to permit its removal

COMPLICATIONS IN FRACTURES OF THE FRONTO-ETHMOIDAL REGION

Complications which occur as a result of frontal bone fractures and of the bones of the interorbital space are numerous and varied First in importance are the lesions of the dura and brain previously described. Fractures of the orbital portion of the frontal bone may cause ocular complications. The margin of the orbit may be splintered and pieces of bone driven into the orbital cavity Lagrange (1917) showed that the thin orbital roof gives way particularly in its posterior part, in the region of the superior orbital fissure and optic foramen A fracture of this type, therefore, tends to injure the optic nerve and the nerves to the extra-ocular muscles which enter the orbit by way of the superior orbital fissure

If the upper rim of the orbit is fractured and the trochlea of the superior oblique muscle is displaced consequent impairment of superior oblique muscle action results in diplopia

Fractures involving the lateral wall of the interorbital space may injure the lacrimal sac tear the ethmoidal vessels or result in deformities due to the overlapping of the bones and detachment of the medial canthal ligament. Sharp-edged bone fragments of the frontal process of the maxilla may be pushed backward into the lacrimal sac. Interference with lacrimal function is manifested by inability to evacuate tears. Infection and suppuration of the lacrimal sac may be the result.

The rupture of ethmoidal vessels may cause a hematoma of the orbit, revealed by marked ecchymosis, proptosis and immobility of the eyeball Such a hematoma is absorbed slowly and antibiotics should be administered to diminish the risk of orbital abscess.

A particular type of deformity consisting of depression of the upper portion of the nose with marked saddle-deformity results when there has been violent trauma backward displacement and impaction of the bones Most characteristic, however of this type of fracture is the widening of the distance between the two inner canthi the medial portion of the orbit is filled with bone fragments pushing the eyeball laterally the medial canthal ligament is detached and the palpebral fissure appears narrowed (see Fig 588 Chapter 21) Such cases often present a mongoloid appearance resembling that seen in epicanthus and hypertelorism (see Chapter 21)

Sinusitis may be caused by disturbance of the cell structure of the ethmoidal sinuses and by obstruction of the fronto-ethmoidal duct.

Severe infection may be complicated by osteomyelitis of the frontal bone in neglected cases

Osteomyelitis of the Frontal Bone

Spreading osteomyelitis of the frontal bone is unusual following trauma localized osteitis following fracture has been observed more frequently Severe comminution of the bone, exposure of the bone by avulsion or extensive laceration of the covering soft tissues and stripping back of the periosteum result in bone necrosis because of deficient blood supply and infection

Signs of infection swelling redness and tenderness appear in the soft tissues over and around the fractured bone. A purulent collection may cause considerable swelling Spontaneous suppuration through the original wound occurs if it is not incised and drained.

Osteomyelitis may involve large portions of the skull the spread of the infection is occasionally rapid, particularly in the frontal region through the diploic veins Such extensive osteomyelitis is rare since the advent of the antibiotics

The roentgenograms may fail to reveal signs of osteomyelitis for a period of approximately twelve days later however the typical moth-eaten appearance of osteomyelitis is easily recognizable a sequestrum may be revealed still later

Antibiotic therapy should be initiated immediately and continued throughout the treatment of the case Bone affected by osteomyelitis or osteitis should be resected at a distance from the diseased area Wide resection of the bone is necessary regardless of the resultant deformity since it prevents meningitis and brain abscess When the removal of the bone has been completed the scalp wound is closed and drains are placed through stab wounds Repair of the bone defect may be undertaken six months later This reconstruction is described in Chapter 20

11

COMPLEX FRACTURES OF THE FACIAL SKELETON

Under the term complex fractures we designate fractures with unusual aspects which require special treatment. In previous chapters, treatment of fractures of individual bones of the face has been discussed singly for the sake of simplicity. In severe injuries, which are becoming more frequent with the accelerated speed of motor driven vehicles, more than one facial bone is usually involved and the treatment of such multiple fractures poses special problems. Not infrequently because of the serious general condition of the patient adequate early treatment has been neglected further complicating the management of the case.

Because these severe injuries present unique problems the usual methods of treatment must be combined to achieve effective results this is best exemplified by the case histories reviewed in this chapter

PRINCIPLES OF TREATMENT OF MULTIPLE FRACTURES

Aside from special means of obtaining reduction and fixation of complex fractures, there are other aspects due often to the serious condition of the patient which requires prime consideration. Purposeful delay may be required the definitive treatment being postponed until the patient's condition is satisfactory blood transfusions, nasal intubation feeding and antibiotics are essential elements of treatment during this period Simple preliminary methods of reduction and fixation such as interdental eyelet wiring prefabricated arch bars and elastic band intermaxillary traction are employed These methods may be adeqate in jaw fractures, and simple reduction of nasal bone or zygomatic fractures may suffice for the definitive treatment but in most multiple fractures more elaborate techniques are required to obtain adequate realignment and permanent fixation of comminuted bone fragments.

The preparation of intra-oral fixation appliances requires taking impressions, a procedure that can be performed on the most severely injured patient, if done with gentleness and skill Bands are prepared for selected teeth and are placed in position when the patient's condition permits.

General anesthesia is indicated in cases requiring open reduction through the external or the intra-oral approach in comminuted fractures of the mandible concomitant with multiple fractures of the bones of the middle third of the face. An elective tracheotomy is advisable to assure the airway and facilitate the administration of the anesthetic.

Combined Maxillary and Mandibular Fractures

In comminuted fractures a prime consideration is the construction of appliances for fixation of the jaw fragments in the correct dental occlusion. Although the re-

constructed cast of the dentition made by realigning the various fragments of the cast is of assistance in determining the occlusion the final relationship of the teeth can be established only in the oral cavity at the time of reduction. For this reason the best type of appliance consists of bands anchored to teeth on the individual fragments, joined by an arch bar which can be adjusted to a suitable curvature in the patient's mouth (see Fig 123 Chapter 6)

In general the following rules are applied (1) the mandibular fragments are immobilized by the use of intra-oral appliances by external fixation when indicated or by direct interosseous wiring (2) the mandible serves as a guide in assembling the maxillary fragments and (3) immobilization of both jaws is accomplished by forcing the teeth of the mandible against those of the maxilla by means of a bandage or headgear The apparatus may consist of a bandage with elastic traction on each side or it may be more complicated a stationary device, such as a bar extended from a mandibular appliance to a headcap or continuous pressure with elastic bands may also be utilized to accomplish the desired result (see Chapter 7)

Combined Maxillary, Nasal and Zygomatic Fractures

The problem of fixation in fractures involving the bones of the middle third of the face alone are less complicated than when the mandible is also involved. Fixation appliances must be devised for the fractured maxillia, nasal and zygomatic bones require immobilization. The following points may serve as a basic guide in the treatment of such fractures

1 Cranial fixation supplies anchorage for appliances and attachments to support fractured nasal and zygomatic bones (see Chapter 7)

2. The maxilla is immobilized care being exercised to restore its normal relationship with the mandible.

3 If the zygoma is not comminuted but simply impacted reduction may be accomplished by one of the methods outlined in Chapter 9 Impaction is usually associated with comminution in the majority of complex fractures more positive methods of fixation than those employed for simple impactions are therefore indicated. The suspension method or direct interosseous wiring may be indicated.

An effort should be made to raise comminuted nasal bones to their normal position (see Chapter 8) When comminution of the nasal bones is associated with other injuries, restoration of nasal contour is not always possible. A secondary operation may therefore be necessary to correct the deformity

The following case histories exemplify the procedures employed in such conditions.

Case Histories

Case 1

This case shows comminuted fracture of the maxilla zygoma and nasal bones and the suspension method of treatment.

A truck passed over the face of a 36-year old circus performer while she was sleeping in a field. She did not lose consciousness, nasal bleeding was profuse and her face was very edematous. She experienced difficulty in swallowing and speaking Ecchymosis was present over the forehead, nose and eyelids The discoloration extended to the angles of the jaw on both sides. The nose was depressed and palpation elicited crepitus Blood issued profusely from both anterior nares. Fragments of the nasal bones extended outward through a 1-cm laceration at the root of the dorsum of the nose

Roentgenograms revealed bilateral comminuted fractures of the anterior wall of the maxillary sinuses, a fracture line extending into the inferior portion of the right orbit. Both maxillary sinuses were cloudy the left zygomatic bone was frac

FIG 302

(*Left*) Appearance of patient with fractures of maxilla, zygoma, and nasal bones six days after injury Note generalized swelling of the face and depression of the middle portion of the face.

(*Right*) Loss of normal occlusal relationship of the jaws with lateral displacement of the maxilla to the right.

tured at the junction of the frontal and zygomatic bones. The nasal bones were comminuted and depressed. The fracture *lines radiated into the ethmoid region. The* patient was examined six days after the accident (Fig 302) At this time considerable edema of the eyelids was present. Flatness of the nose and lateral and backward displacement of the maxilla could be seen. Clinical examination verified the roentgenographic findings. There were no symptoms indicating meningeal irritation.

Under general anesthesia a curved incision was made at the frontozygomatic junction 1.5 cm behind the external canthus of the eye. The site of the fracture was exposed and the zygoma and frontal bones were wired together The anterior surface of the left maxilla was exposed through an intra-oral incision. The maxillary sinus was also exposed and loose necrotic bone fragments, found floating in blood clot were removed A nasoantral opening was made for drainage in the inferior meatus. The fracture line was located and a hole drilled *just beneath the infra-orbital margin* on each side of the fracture. Wire was inserted through the holes and the ends passed through the skin of the face Each end was twisted into a button to be utilized later to suspend the loose fragments. Wire buttons were formed around selected upper and lower teeth to be used later for reduction of the fractured maxilla Figure 303 is a roentgenogram showing the site of fracture and the wire suspension method employed The splint shown in Figure 262 (Chapter 8) was employed for the reduc*tion and immobilization of the fractured* nasal bones. Following recovery from anesthesia elastic band traction was applied to the infra-orbital wire button to the nasal *splint and to the buttons on the teeth*

Five days later the occlusion of the teeth

Fig 303 Roentgenogram of case shown in Figure 304

appeared almost normal but there was still slight vertical mobility of the upper jaw The nasal splint was adjusted eight days postoperatively (Fig 304) Fifteen days post operatively the headcap and nasal splint were removed and a Barton bandage was applied with elastic pressure on each side to force the teeth of the mandible against those of the maxilla (Fig 305) On the nineteenth day much of the swelling had disappeared and the countour of the nose and face was considerably improved. The left maxillary sinus was irrigated daily

On the twenty-eighth day following operation all the wires were removed from both jaws, occlusion of the teeth had been attained (Fig 306) and the maxilla seemed firmly anchored. The patient was discharged nine days later

Examination nine months after the injury revealed normal occlusion normal nasal contour and healthy nasal mucosa with no obstruction (Fig 307)

This case history demonstrates the value of direct interosseous wiring and transcutaneous wire suspension to exert traction in a severely comminuted fracture of the bones of the middle third of the face. Intermaxillary elastic band traction was applied after the patient was fully conscious, an essential measure to achieve the restoration of dental occlusion

Case 2

This is a case that includes comminuted fracture of the maxilla with craniofacial dysjunction and cerebrospinal rhinorrhea comminuted fracture of the nasal bones and zygoma and bilateral fracture of the neck of the condyle.

A man aged 28 years was injured in an automobile and train collision (Fig 308) A copy of the findings in this case as re-

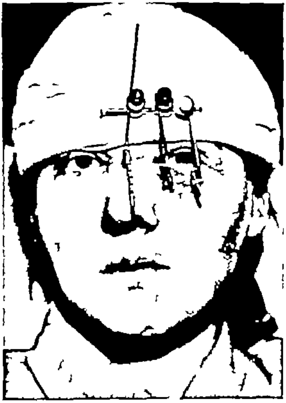


FIG 304 Photograph showing suspension of maxillary and zygomatic fragments by wires brought out through the skin and elastic traction. The U-splint maintains elevation of comminuted nasal bones (see also Figs. 260 261 262 and 282) Cranial fixation of the appliance is maintained by a plaster headcap.

ported by the radiologist exemplifies the extent of damage to structures that may occur in complex fractures involving the jaw bones and the nasal and zygomatic components of the face. The report of the radiologist follows There are multiple fractures of the bones of the face with marked displacement. There is a fracture-dislocation of both zygomatic bones, the right one being displaced downward and outward the zygomatic arch is broken in two places, and displaced downward. The anterior wall of the frontal sinus is fractured, and with the comminuted nasal bones is depressed backward and downward This fracture extends into the cribriform plate The inner rim of the right orbit is displaced into the orbital cavity There is a transverse fracture of the maxilla the bone is displaced backward downward and to the left. The nasal septum is comminuted. There are transverse fractures of the neck of both condyles, with no displacement There is a fracture of the left lower jaw in the incisor region with the loss of the central and lateral incisors. The alveolar process is broken about the canine The root of the upper left bicuspid is fractured, and the third molar is loosened from its socket" (Fig 309)

Examination disclosed a greatly swollen face the skin over the nose was lacerated the nasal bones were crushed inward there were also lacerations of the lip side of the face, and tongue. Crepitus was elicited in the right temporal region there was looseness of both jaws (Fig 308*A* *B*) Clear fluid, resembling cerebrospinal fluid was observed draining from both nostrils this con

FIG 305. After reduction the headcap has been removed. A Barton bandage with elastic traction on each side (see Fig 214) maintains the teeth of the mandible against those of the maxilla while consolidation is progressing Note wire button in the left infra orbital area. These wires were used for traction as in Figure 304

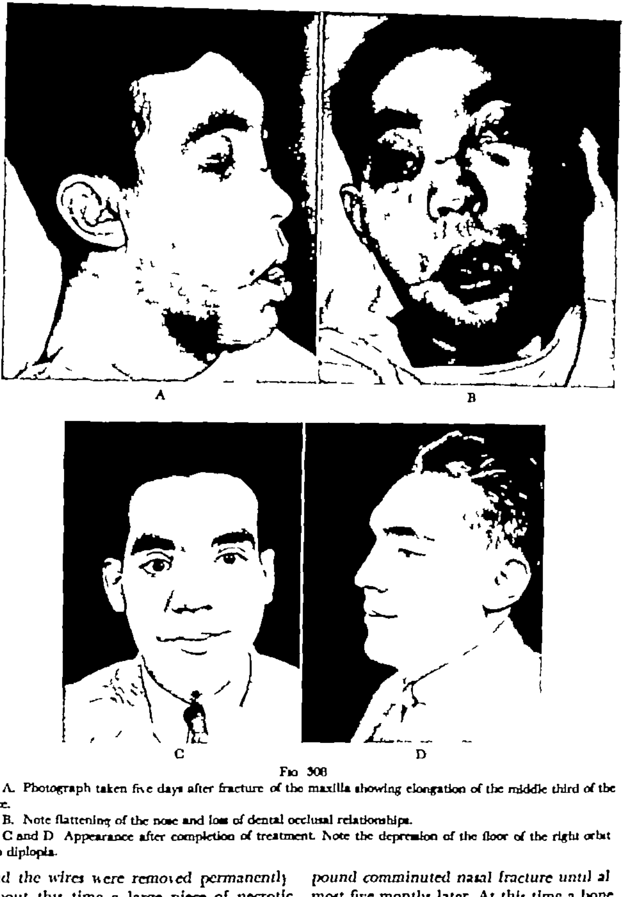
Fig 306. Normal occlusal relationship of the upper and lower jaws restored (compare with Fig 302, *Right*)

tinued for four days then ceased No indications for neurosurgical intervention were found.

A Barton bandage with adjustable elastics on both sides was applied to support the jaws Because of the patient's serious condition only supportive therapy was continued until eight days later at this time impressions were taken for the construction of intra-oral fixation appliances. On the following day a Kingsley type of splint was adjusted to the upper jaw and a band and arch bar appliance to the lower It may be mentioned at this time that all of these, and most subsequent procedures were performed at the bedside because of the patient's condition The maxillary sinus was exposed through the canine fossa under local anesthesia pus was evacuated, and a nasoantral opening was established for drainage. Fifteen days postoperatively a lower canine tooth in the line of fracture was removed a submental abscess required incision and drainage

The appliances were removed ten weeks after injury the lower jaw had consolidated but because the upper jaw was still mobile the jaws were rewired in occlusion. Two months later the maxilla was firm

Fig 307 Photographs of patient at completion of treatment (see Figs. 302 to 306)



A B

C D

Fig 308

A. Photograph taken five days after fracture of the maxilla showing elongation of the middle third of the face.

B. Note flattening of the nose and loss of dental occlusal relationships.

C and D Appearance after completion of treatment. Note the depression of the floor of the right orbit No diplopia.

and the wires were removed permanently About this time a large piece of necrotic bone was recovered from within the nose.

No attempt was made to correct the com*pound comminuted nasal fracture until al*most five months later At this time a bone graft was inserted along the dorsum of the nose and a fascial transplant was employed

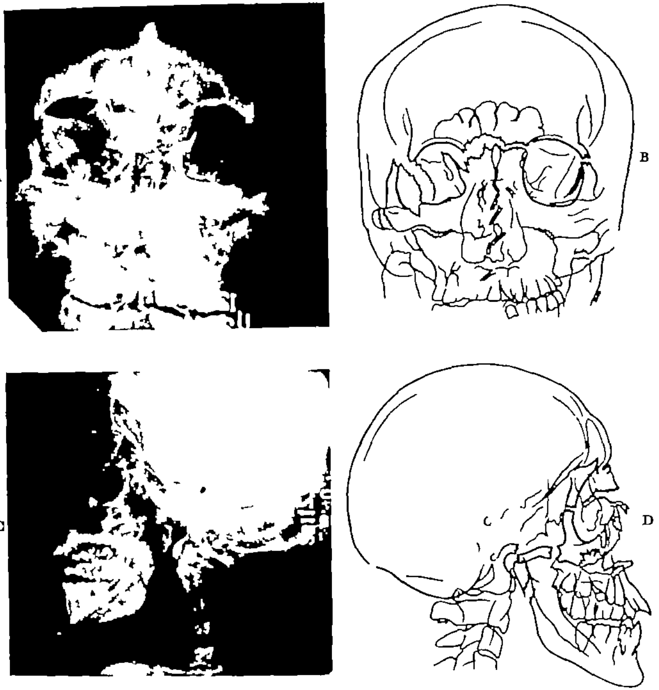


FIG 309

A. Anterior-posterior roentgenogram of case shown in Figure 308

B. Outline tracing of roentgenogram showing fractures.

C. Lateral roentgenogram of case shown in Figure 308

D Outline tracing of roentgenogram showing fractures.

to eliminate the depression of the left superior palpebral fold (Fig 308 *C* and *D*)

This case history illustrates the value of purposeful delay of the definitive treatment of the facial bone fractures until the patient's general condition is fully assessed and the need for an early neurosurgical intervention eliminated Eight days after injury impressions of the teeth were taken and intra-oral arch bar and band retention appliances were made for the definitive reduction and fixation of the fragments.

Case 3

This case was a gunshot injury of the maxilla and mandible with loss of bone. A 28-year old Moroccan soldier suffered compound comminuted fractures of the maxilla

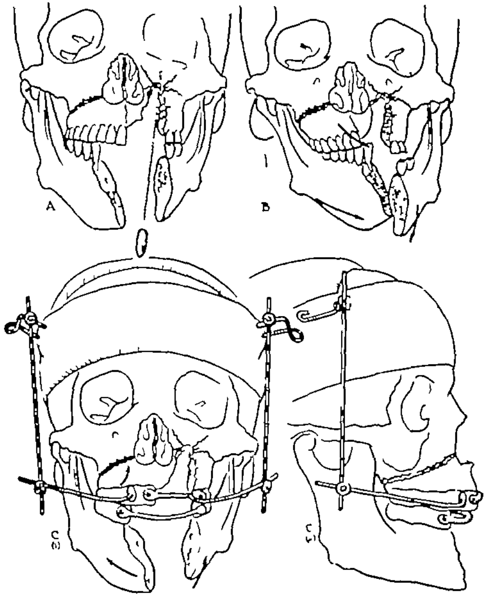


Fig 310. Treatment of complex fracture involving the maxilla and mandible with loss of bone

A. Loss of bone in the maxilla and mandible caused by machine gun bullet.

B. Medial displacement of the unsupported fragments.

C_1 C_2 Illustrate fixation of maxilla to the headcap and of the mandible to the maxilla. Note the sectional splints.

(J M Converse, J Oral Surg 3 112, 1945)

and mandible with loss of bone. The injury resulted from a machine gun bullet during World War II

Marked medial displacement of the unsupported maxillary and mandibular fragments occurred during the next two weeks (Figs. 310 to 312) The patient was examined at this time and immobilization of the various fragments was accomplished in the following manner The continuity of the maxillary arch was re-established by an intra-oral sectional appliance extensions were soldered to the appliance permitting cranial fixation to a plaster headcap (Fig 313) The maxilla was chosen for cranial fixation because the degree of displacement of the maxillary fragments was less than that of the mandibular portions. The next problem was to correct the medial displacement of the mandibular fragments which were fixed by fibrous adhesions this could not be achieved without incising through

FIG 311 Photograph of patient showing deviation *of the lower part of the face* resulting from loss of bone and displacement of mandibular fragments as illustrated in Figure 310 A, B.

(Figs. 311 to 313 J M Converse, J Oral Surg., 3 112 1945)

FIG 312 Shows loss of dental occlusion due to displacement of mandibular fragments of case shown in Figures 310 and 311

FIG 313 (*Left*) Occlusal relationship restored by sectional splints *note the lateral arms extending from the* maxillary splint to the cranial fixation apparatus.

(*Right*) Appearance of the patient at the completion of the fixation procedures. The connection between the lateral arms and the headcap accomplished by means of Kirschner wires attached by joints used in the external fixation apparatus for mandibular fractures (see Fig 224)

the adhesions to free the fragments. An intra-oral sectional cap splint was constructed in two halves and an intermediary lock bar was planned (see Figs. 124 128 Chapter 6) The appliances were cemented to the teeth in each fragment. The binding fibrous tissue was sectioned under general anesthesia the freed fragments were placed in proper dental occlusion and were fixed by intermaxillary wire ligatures. The lock bar (see Fig 124) was placed between the two halves of the sectional splint one hour later (Figs. 310C 313) This allowed the early removal of the intermaxillary wiring thus permitting the patient to open the mouth

The use of the sectional splints and lock bars illustrated in this case permitted fixation of the fragments in their correct anatomical position until the gap in the bone could be filled by a bone graft.

Case 4

This case illustrates compound comminuted fracture of the maxilla nasal bones and zygomas.

A 54 year-old man was admitted to Bellevue Hospital in a state of shock after having *sustained a crushing injury to the middle* third of his face one hour and a half prior to admission (Fig 314A) While cleaning the top of an elevator he leaned over and was struck on the bridge of the nose by a descending elevator in the adjacent shaft. The blow produced a comminution of the nasal bones and a horizontal fracture extending across the face immediately below the rim of the orbit and through the anterior wall of both maxillary sinuses. The portion of the facial skeletal framework below the horizontal fracture line was detached from the remainder of the face and cranium the gap in the nasal area being about 2 cm in width (Fig 315). Clinical examination confirmed by roentgenographic examination showed that the middle portion of the face was extremely mobile and that the horizontal fracture line extended laterally through the body of the zygoma on each side. The entire middle third of the face below the fracture line *moved in unison with the mobile upper* maxilla Intra-oral examination showed a disturbance of the dental occlusion due mostly to a sagittal palatal fracture.

Because of the location of the injury and the presence of a sero-sanguinolent nasal *discharge a neurosurgical consultation was*

Fig 314 Compound comminuted fracture of the maxilla, nasal bones and zygoma

A. Appearance of patient one hour and a half after injury Note separation of the bones in region of nasal bones and left maxilla.

B. Appearance of the patient after bony consolidation.

C. Final appearance of the patient after bone grafting to the dorsum of the nose bilateral dacryocystorhinostomy and scar repair

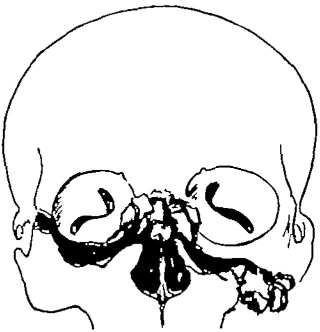


FIG. 315. Tracing of roentgenogram showing the fractures in patient shown in Figure 314

requested. After considering the clinical and radiological findings the probability of a head injury was ruled out. Efforts were made to collect sufficient fluid from the nasal discharge for chemical tests to demonstrate cerebrospinal fluid insufficient fluid was obtained to perform the test.

Careful manipulation of the maxilla showed that it was possible to replace the downward displaced skeletal structures and to close the gap in the region of the nasal bones. A plaster headcap was constructed and an emergency Kingsley splint (see Fig 221 Chapter 7) was applied to maintain upward pressure upon the maxilla. Reduction and fixation were done in bed a few hours after the injury following the patient's recovery from shock. The upward pressure exerted by the Kingsley splint and the cranial fixation closed the bony and soft tissue gap so efficiently that primary suture of the soft tissue wounds was not necessary

Three weeks after the injury the Kingsley splint and cranial fixation were removed and the teeth of the maxilla and mandible were maintained in occlusion by intermaxillary fixation. A removable headgear was employed to maintain upward pressure upon the maxilla. The patient was discharged five weeks after the injury (Fig 314*B*)

Later procedures included a bone graft to the dorsum of the nose (Fig 314*C*) and a bilateral dacryocystorhinostomy as the patient developed obstruction of both nasal

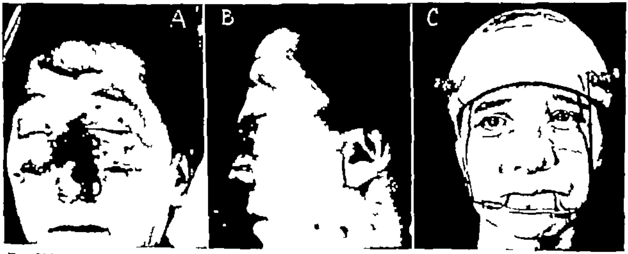


FIG 316. Compound comminuted fracture of the maxilla, nasal bones and right and left zygoma (case of Dr E. M. Holmes)

A. Appearance of the patient soon after the accident. The patient was thrown against the windshield when the car crashed against a tree. Note downward displacement of the maxilla and the gap in the region of the nasal bones.

B. Note the backward and downward displacement of the maxilla.

C. Appearance of the patient after reduction, cranial fixation with Holmes's version of the Kingsley splint and suture of the soft tissues.

Fig. 317 Comminuted compound fracture of the maxilla, nasal bones right and left zygoma and mandible

A and C. Appearance of the patient following injury in a head-on automobile collision.

B and D. Appearance of the patient after consolidation of the fractures.

lacrimal ducts. These structures were probably torn at the time of the initial injury

Although cerebrospinal rhinorrhea was suspected but could not definitely be demonstrated in the absence of clinical or radiological signs, the case was treated conservatively with good results.

A complex fracture treated with similar methods is illustrated in Fig 316 Primary suture of the soft tissue wound was done after replacement of the maxilla.

Both of these case histories indicate the value of cranial anchorage and the use of the Kingsley splint to achieve reduction and fixation of the loose downwardly displaced fractured maxilla The principle of obtaining closure of the soft tissue wound of the compound fracture by approximating the bony fragments is also demonstrated

Case 5

A 49-year-old man the sole survivor of four occupants of an automobile involved in a head-on collision with another car was transferred to the hospital four days after his injury (Fig 317*A* *C*) Examination showed multiple comminuted fractures of the maxilla nasal bones, both zygomas the mandible and a soft tissue wound over the bridge of the nose (Fig 318) His condition upon admission was poor due to a head injury suffered in the accident the patient had remained unconscious for twenty four hours. Blood transfusions, high caloric feeding by nasal intubation and antibiotic therapy were administered Impressions for intra-oral fixation appliances were taken and temporary immobilization of the fractured jaws was established

Four days after admission an elective tracheotomy was done under local anesthesia and general anesthesia was then administered through the tracheal opening Bands were cemented to selected teeth on the two maxillary and three mandibular fragments. Reduction was achieved by manipulation of the fragments fixation was assured by means of intra-oral arch bar appliances and intermaxillary elastics. The comminuted fragments of the right zygoma showed only slight displacement and were

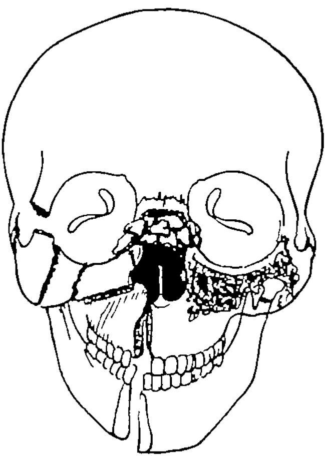


FIG 318. Tracing of roentgenogram showing the fractures in patient in Figure 317 An additional fracture line in the mandible is omitted in the drawing

FIG 319 Casts of dentition of patient shown in Figure 317

A and C. Preoperative views.

B and D Postoperative views.

not disturbed. The bone of the left zygoma and infra-orbital portion of the maxilla was finely comminuted and depressed posteriorly. This area was exposed through the intra-oral approach; the maxillary sinus was entered through the shattered anterior wall of the sinus. Gauze strips impregnated with Aureomycin ointment were packed into the bony fragments. The nasal bone fragments and the septum were manipulated into alignment, the soft tissue wound was sutured and a molded dental compound splint was applied.

The patient made an uneventful recovery (Fig. 317*B*, *D*). The tracheotomy tubes were removed one week after operation and the maxillary sinus packing was removed on the twelfth postoperative day.

In this case intra-oral impressions were taken in advance of the operative procedures, casts of the dentition were made (Fig. 319), bands were prepared and placed on the selected teeth while the patient was under anesthesia. Intermaxillary fixation appliances were constructed and fastened to the dentition. A tracheotomy was done to assure the airway and facilitate the anesthesia. Finally, packing in the maxillary sinus was the only method available to support the finely comminuted bone fragments.

12

FACIAL INJURIES IN CHILDREN

Facial injuries in children are considered separately in this text because of special problems which arise in treatment. Soft tissue injuries and fractures may require special methods due to difficulties in obtaining the co-operation of young children. Another aspect of facial injuries in children is that which results from the influence of trauma upon facial development. A facial deformity due to trauma in a child is the result not only of the displacement of bony structures due to fracture, but also to faulty development resulting from the injury Developmental malformations seen in young adolescents and adults are often the result of early childhood injury

Birth Injuries

The mechanical strains and stresses of birth when delivery is prolonged or aided by instrumental means may lead to a wide variety of facial injuries. Fortunately most of the injuries are mild and the effects are transient. More severe injuries have been attributed to forceps compression of the soft tissues and bones of the face resulting in permanent facial scars and of the bone in the region of the zygomatic arch and temporomandibular joint, resulting in temporomandibular ankylosis with subsequent developmental atresia of the mandible. Because of the lack of development of the mastoid process at birth and the superficial position of the seventh nerve facial paralysis, due to injury of the nerve by delivery forceps pressure is sometimes observed.

Injuries to the eye or its adnexae such as damage to the extra-ocular musculature, may be caused by intra-orbital hemorrhage Fractures of the body of the mandible due to birth injury are rare Those seen by the authors have been simple linear fractures with little if any displacement healing occurring in a short time without manipulative treatment.

Soft Tissue Injuries in Children

Soft tissue wounds in children heal rapidly and therefore require primary suture early Such wounds tend to heal with considerable hypertrophic scarring discouraging results often require later secondary repair of the scars (see Chapter 16) Scars in children usually soften and lose their red color with the passage of time thus becoming less noticeable they tend to widen however as the face grows It is wise to mention this possibility to the parents, advising them that later secondary surgery may be necessary Densely scarred areas may require reconstructive procedures, for such untreated areas may interfere with subjacent bony growth particularly in the area of the mandible

Fractures

Considerable trauma is required to produce a fracture in children because of the relative elasticity of the bony structures. The fractures suffered by children are similar to those incurred in adults, but these are influenced by the fact that in young

children and infants some suture lines are not yet closed. Despite satisfactory healing and consolidation fractures of the jaws may also cause derangement of developing tooth follicles and faulty eruption of teeth. The influence of the fracture on growth centers of the jaws may result in developmental malformation

Fractures of the Mandible

Our records indicate that approximately ten per cent of mandibular fractures have occurred in children between the ages of four and eleven years. While the fundamental principles of treatment of these fractures do not differ materially from the treatment of fractures in adults, special aspects should be emphasized.

1 In this age group the developing permanent teeth occupy most of the body of the mandible (Figs. 320 to 322) The roots of the deciduous teeth are gradually being resorbed and between the ages of five and nine years, because of the mixed dentition and the frequent absence of teeth it is often difficult to utilize the dentition for immobilization

2. The reparative process in children is rapid loose displaced fragments become quite adherent to one another within three or four days after the injury At this time fragments are difficult to manipulate and must be loosened under general anesthesia before reduction of the fracture is possible

3 Children are not expected to be co-operative and even minor manipulative work, such as intermaxillary wiring or the making of wire loops or buttons, should be performed under general anesthesia Some children if the need for treatment is carefully explained to them become remarkably co-operative.

The developing bone predisposes to the "greenstick type of fracture. Fractures involving the body of the mandible frequently show a considerable degree of displacement and the fracture lines tend to be long and oblique extending downward and forward from the upper border of the mandible. This obliquity of the fracture line is quite different from that observed in the adult where the direction of the fracture line is usually downward and backward.

Fractures of the condyle which involve the base of the neck of the condyle are usually of the "greenstick variety and are not

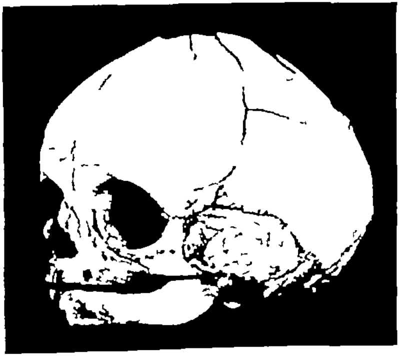


FIG 320. Skull of infant first year of postnatal life

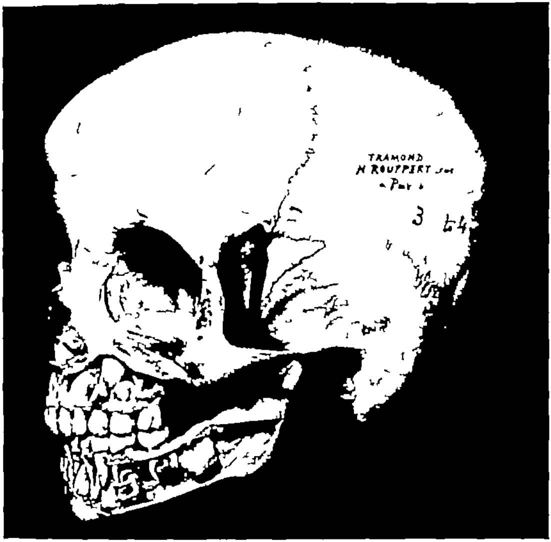


FIG 321 Skull of a three-year-old child showing the position of the buds of the permanent teeth in relation to the temporary dentition.

usually accompanied by disturbance of the temporomandibular joint. The high level fracture, with dislocation of the head of the condyle must always be viewed with concern in the young child because of the possibility of secondary growth anomalies from damage to the condylar growth center

Temporomandibular joint injury may lead to ankylosis One of our patients a 3-year-old boy was examined following a fall on the chin No apparent injury could be found on clinical and radiological examination Six months later the child had developed marked limitation of motion of the mandible due to partial ankylosis of the right temporomandibular joint. Resection of the condyle restored mandibular function

Fractures involving the body of the mandible frequently involve the permanent tooth follicles but it is seldom necessary to remove these Eruption of the permanent teeth may be delayed and the teeth may show varying degrees of damage following consolidation of the fracture.

It is often advisable for the child to be sedated prior to x ray examination in order to obtain clear films Treatment of fracture in the young child should be rapid reduction and fixation should be accomplished in one operation whenever possible. The teeth are used for intermaxillary or horizontal wiring or for the retention of appliances when possible.

An 11 year-old girl was struck by the revolving blades of an outboard motor af

FIG 322. Skull of a child in the seventh year showing the position of the buds of the permanent teeth in relation to the temporary dentition.

ter she fell off a surf board She suffered a compound fracture of the frontal bone on the right side with tearing of the dura mater and cerebrospinal fluid leakage and a compound comminuted fracture of the body of the mandible with lacerations of the corner of the mouth cheek neck and floor of the mouth on the right side The patient was rushed to a hospital where she received excellent emergency treatment the lacerated dura mater forehead skin and cheek were sutured and fixation of the fractured mandibular fragments was improvised by means of catgut. She was transferred and was operated upon ten days later after her general condition had improved and the cerebrospinal leakage had ceased Under general anesthesia the still movable mandibular fragments were realigned and immobilized by a cable arch wire appliance (Fig 323) the remaining teeth were maintained by intermaxillary fixation (Fig 324) Later the cable arch wire appliance was replaced by a band and arch-bar appliance

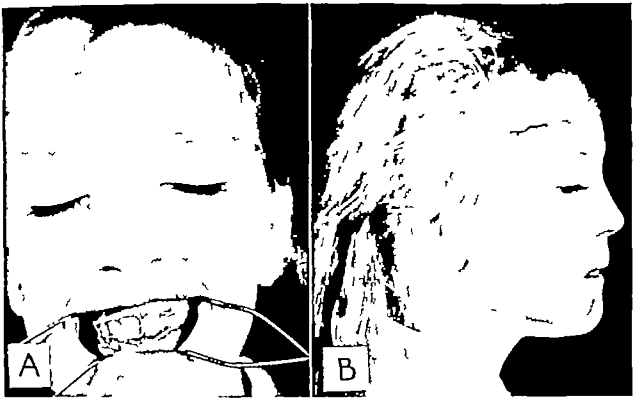


Fig 323

A. Cable arch wire appliance employed in a child with compound comminuted fracture of the mandible (see Fig 324)

B. Photograph showing sutured wounds of the forehead and cheek. Suture marks due to large size suture material employed prior to admission.

This case illustrates two points of interest (1) the efficient primary treatment which not only saved the patient's life but also minimized deformity and simplified subsequent treatment and, (2) the use of a temporary cable arch appliance followed later by a definitive band and arch bar appliance using erupting teeth for anchorage other teeth, usually relied upon for such fixation had been lost at the time of injury

When there are insufficient teeth for anchorage we resort to direct interosseous wiring through the alveolar process. The patient shown in Fig 325 aged 7 years, sustained bilateral comminuted fractures of the body of the mandible in an automobile accident (Fig 326) The middle fragment of the body of the mandible was displaced downward and the occlusion of the teeth was markedly disturbed with an open-bite (Fig 325*A*) Under general anesthesia attempts were made to apply bands to the molar teeth but the bands could not be re-

Fig 324 Roentgenogram showing comminution of the body of the mandible on the right side and cable arch wire appliance providing fixation.

tained because of the small size of the teeth The bone fragments were aligned and ap-

FIG 325

A. Photograph showing open-bite in a child with bilateral fracture of the body of the mandible (see Fig 326)

B. Appearance of patient and removable headgear

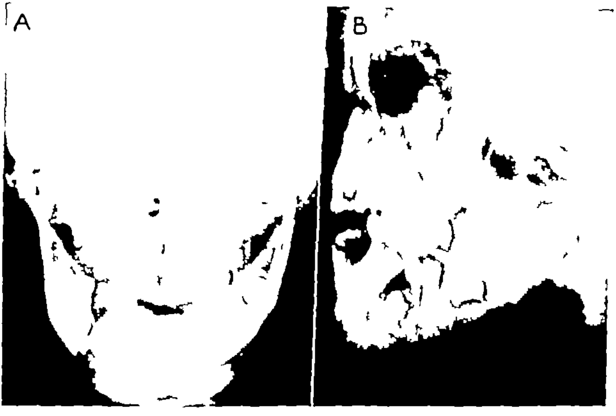


FIG 326

A. Roentgenogram showing fracture of the body of the mandible

B. Roentgenogram showing consolidation in correct alignment

proximated by direct interosseous wiring through the intra-oral approach using the pull-out wire technique (see Fig 176 Chapter 6) Because of the impossibility of utilizing the teeth for intermaxillary fixation a removable headgear (see Fig 215 Chapter 7) was employed to maintain the correct occlusion of the teeth The postoperative

course was uneventful and the wire was removed under local anesthesia one week later Final alignment of the bone after consolidation of the fracture afforded a satisfactory result (Fig 326*B*)

If reduction has been delayed and cannot be achieved through simple manipulation the fibrous tissue which forms rapidly between the ends of the fragments in children is incised and loosened in order to regain mobility of the fragments. A stout needle or trochar establishes a hole through the alveolar process of the distal and proximal fragments. Fine stainless steel wire is then passed from the buccal to the lingual side across the fracture line and returned from the lingual to the buccal side. The fragments are manipulated into normal position and the ends of the wire are twisted together The twisted ends are bent close to the alveolar process and left long enough to protrude through the gingival tissue.

Although this procedure occasionally may cause injury to unerupted teeth little damage has occurred in our cases. Even though one or more teeth must be sacrificed eventually less harm ensues than would occur if the jaw fragments were permitted to heal in a distorted position which may lead in children to greater deformity than in adults.

Fractures of the Maxilla and Zygoma

Fractures of the maxilla occur less often in children than in adults. The treatment of maxillary fractures in children is similar to that of the fractured mandible

Although less frequent than in the adult, fractures of the zygoma in children are usually of the fracture-dislocation type especially because of the lack of complete union of the frontozygomatic suture.

Fractures and Dislocations of the Nasal Bones and Cartilages

As previously described in Chapter 8 the nasal bones in children are separated in the mid line by a suture line The open-book type of fracture, with overriding of the nasal bones over the frontal process of the maxilla is a frequent type of fracture due to the presence of this suture line between the nasal bones Fractures and dislocations of the septal cartilage are frequent and hematoma of the septum is always a serious complication in children not only because of nasal obstruction which results from widening of the septum but also because of the possibility of saddling which occurs along the dorsum due to loss of cartilage produced by pressure necrosis or a septal abscess Flattening of the nasal dorsum often combined with thickening of the nasal septum results in marked nasal obstruction which may require early corrective procedures in children The deformity characterized by depression of the dorsum with widening of the nasal bridge may require correction for psychological reasons The technique for repair of these deformities is discussed in Chapter 22.

Nasal Deformities in Children

Relief from nasal obstruction is important in deviations of the nose in children Surgical procedures to remedy nasal obstruction are indicated these may vary from the conservative operation for straightening the septum to more complex procedures described for straightening the nasal pyramid (see Chapter 22)

When a child shows a saddle-deformity of the nose, the parents may be concerned over the deformity and request a corrective operation It is always preferable to postpone such an operation until the age of 16 or 17 years. If operation is indicated for functional reasons, such as nasal obstruction or for psychological reasons, an implant of cartilage or bone is employed. Cartilage and bone resected from the septum in a submucous operation for the relief of nasal obstruction cartilage from the concha, or bone from the ilium are satisfactory grafts. The iliac bone in the child and the adolescent is cartilaginous along the crest. In removing bone from the ilium in children the cartilaginous portion of the crest should

not be employed, for in our experience transplanted epiphyseal iliac cartilage is progressively absorbed The cartilaginous *portion of the bone is incised along its* junction with the body of the bone and raised upward and medially the cartilage is not separated from the muscles of the trunk by this method and the major part of the blood supply is preserved. Bone grafts are then removed and the iliac crest is replaced in its anatomical position

Developmental Malformations of the Facial Skeleton due to Trauma

Many developmental malformations can be attributed to trauma in early childhood. Others cannot be attributed to traumatic injury and appear to be of congenital origin and often hereditary Typical jaw malformations are seen from generation to generation in the same family

In order to understand some of the developmental deformities resulting from injury a review of facial development follows.

Postnatal Growth of the Face

Knowledge regarding cranial facial growth has been determined by a variety of methods reviewed by Gans and Sarnat (1951) The cross sectional approach requires the utilization of large numbers of *skulls of varying ages (Helman 1927 Keith* and Campion 1922 Krogman 1930) Other methods can be employed which permit serial measurements on the same growing individual to evaluate the actual amount of growth Four principal methods have been employed (1) the utilization of vital stains by means of madder as first practiced by John Hunter (1835–1837) or (2) vital staining of calcifying bones by means of a single intraperitoneal or intravenous injection of a 2 per cent solution of alizarin red (Schour Hoffman Sarnat and Engel 1941) (3) Gans and Sarnat (1951) utilized implants of amalgam on each side of the frontozygomatic, frontomaxillary zygomaticomaxillary zygomaticotemporal and premaxillomaxillary sutures. These implants were placed after incisions were made in order to expose bony areas. (4) Serial cephalometric roentgenograms have been employed by Broadbent (1931 1937) Margolis (1940 1947) Higley (1936) and Gans and Sarnat (1951)

The growth of the face is rapid and is best illustrated by the change in facial size

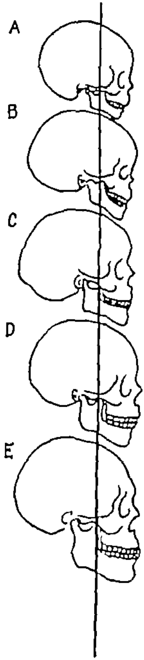


Fig 327 Tracings of a series of skulls showing changes in the size of the face and also of the position of the face in relation with the cranium The growth of the face is associated with the growth of the jaws and the eruption of the teeth (after Hellman, 1931)

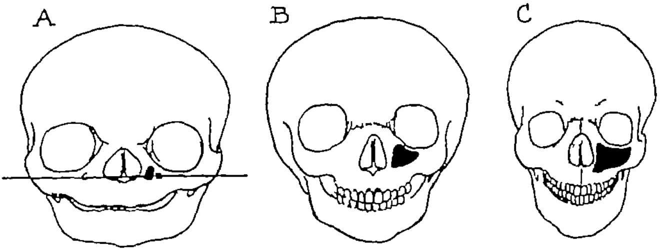


FIG 328. The skull at birth (A) at five years (B) and in the adult (C) have been drawn with the same vertical dimension to show the relative size increases of the maxillary sinus Note the progressive increase in size of the maxillary sinus, extending laterally beyond the infraorbital foramen (B) and descending below the level of the floor of the nose (C) after the eruption of the permanent teeth.

at three months the face is less than half the size of that of the adult (approximately 40 per cent) At two years it has reached approximately 70 per cent, at five and one half years it attains approximately 80 per cent of the adult size (Fig 327)

The proportions of the face change markedly during postnatal growth The skull at birth presents a relatively large cranial portion and a small facial portion when compared with the skull of the adult thus the proportions are 8 to 1 at birth in favor of the cranial portion over the facial portion 4 to 1 at five years, and 2 to 1 in the adult (Fig 327)

These changes are due to two factors (1) the actual growth of the face and (2) the modification of the proportions which bring forth characteristics distinguishing the faces of males from those of females and also distinctive individual features.

1 THE GROWTH OF THE FACE. The facial skeleton is relatively small at birth The nasal fossae and paranasal sinuses are also small (Fig 328*A*) the nasal fossae are as wide as they are high. The pyriform aperture is broad and its lower border and the floor of the nasal fossae are on a level slightly below that of the lower rim of the orbit and a horizontal line passing approximately through the two infra-orbital foramina (Fig 328*A*)

The growth of the maxillary sinus is concomitant with the growth of the face. The maxillary sinus is narrow in the newborn and is not sufficiently developed to reach beneath the orbit (Fig 328*A*) the sinus increases in size progressively During the first year the medial lateral dimensions have reached beneath the orbit but no further laterally than the infra-orbital foramen. During the third and fourth years the medial lateral dimension of the maxillary sinus has increased considerably at five years it extends considerably lateral to the infraorbital canal (Fig 328*B*) The floor of the maxillary sinus remains above the level of the floor of the nose in the child up to the age of 8 years It is only after the eruption of the teeth, in the twelfth year and the development of the alveolar process, that the maxillary sinus descends below the level of the floor of the nose (Fig 328*C*)

Increase in the vertical dimension of the face is due in part to the development and eruption of the dentition. In the newborn the height of the crown portions of the upper and lower teeth or of the alveolar processes are not included (Fig 320) A gradual facial change has occurred at 7 years as a result of a general increase in size in all dimensions (Fig 322) The completion of facial growth varies occurring from the eighteenth to the twenty fifth year

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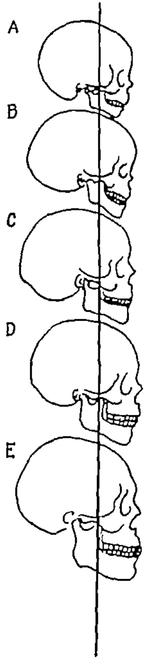

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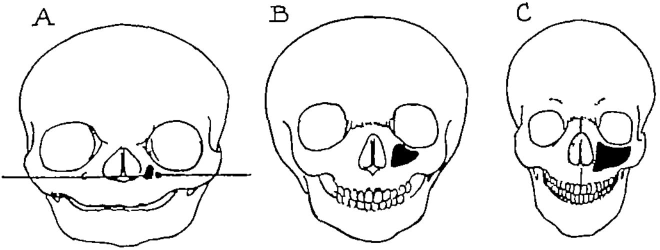

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FIG. 329

A. Photograph of the same individual at three months and at twenty-three years of age showing the transformation of the face from infancy to adulthood.

B. Photographs of the same individual at three months and twenty-three years of age, showing similarity in size but difference in form The photograph on the left has been enlarged in order that the vertical dimension of the face be the same as in the photograph on the right.

(From M Hellman, "The Face In Its Developmental Career" in *The Human Face—A Symposium* The Dental Cosmos, Philadelphia, 1935)

2. CHANGES IN PROPORTION OF THE FACE. The increase in facial height is greater in the middle third of the face than in the lower third the increase in the anterior posterior direction is greater in the lower jaw than it is in the upper jaw and the face widens more in the lower jaw than in *the upper jaw*

The changes in the proportions of the face during postnatal growth are well illustrated by comparing the face of a 3-month old infant with that of the same individual at the age of 23 years (Fig 329*A*) The growth of the middle and lower thirds of the face are striking (Fig 329*B*)

At birth the portion of the nasal fossa occupied by the ethmoid is twice the height of the maxillary portion During childhood the growth of the maxillary portion is accelerated, approximating the ethmoidal portion at the seventh year when adult proportions are attained This growth of the maxillary portion of the nasal fossa is due in part to the increase in size of the maxillary sinus and to the development of the dentition and supporting alveolar processes. The forward growth of the maxilla and mandible produces striking changes in the profile of the growing head (Fig 327) tracings reveal the increase in facial height which occurs posteriorly as a result of the vertical growth of the ascending ramus of the mandible Changes in the maxilla and mandible result in characteristic changes of profile (Fig 330)

The peak of growth in the head and face occurs between three and five years After this period growth proceeds slowly but an acceleration occurs again between the thirteenth and fifteenth years Growth is greatly diminished after the age of fifteen Growth of the nose is completed between the eighteenth and twenty fifth year From a surgical standpoint one may consider the growth of the nose completed at about the age of sixteen years. Changes occur throughout life. Uneventful growth of the face produces a normal face interference with growth results in deformity Nasal asymmetry and deviation are frequent results of trauma in infancy or childhood

Postnatal Growth of the Mandible

The mandible is most frequently involved in developmental malformation In order to explain the influence of extraneous factors upon the development of the mandible one should recall the embryological development of this bone.

The dorsal part of the first or mandibular arch grows forward beneath the developing eye region to the olfactory area forming the maxillary process As the result of the formation of this process the mesenchymatous condensation which gives origin to the first pharyngeal arch becomes bent and part of this dorsal portion becomes chondrified forming a small cartilaginous mass which represents the pterygoquadrate bar of lower vertebrates (see Chapter 1) The remaining

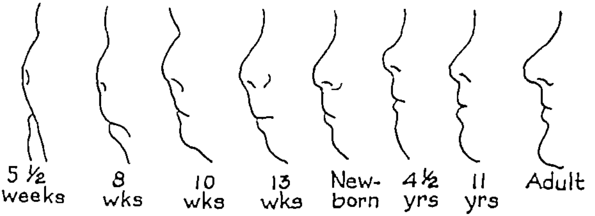

FIG 330. Series of profile outlines of the face from five and one-half weeks to the adult. Adapted after ... and Schaeffer

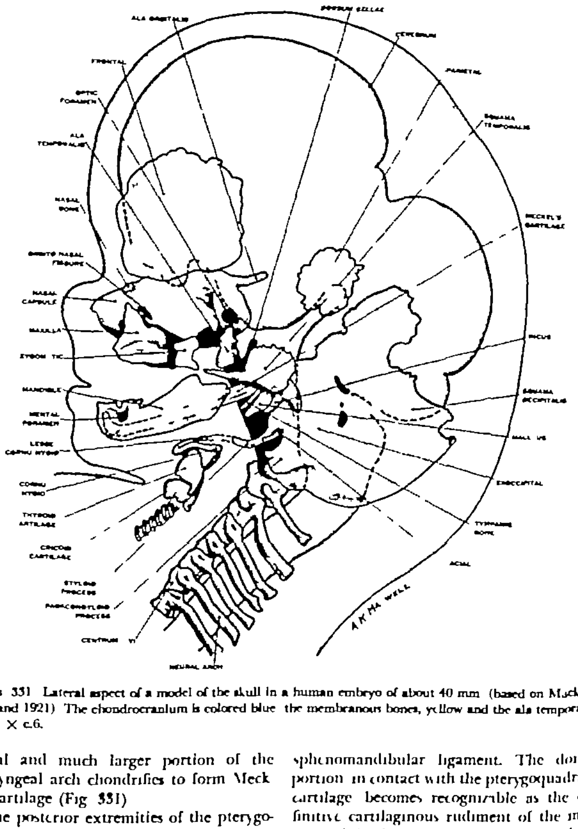

Fig 331 Lateral aspect of a model of the skull in a human embryo of about 40 mm (based on Macklin, 1914 and 1921) The chondrocranium is colored blue the membranous bones, yellow and the ala temporalis green. × c.6.

dental and much larger portion of the pharyngeal arch chondrifies to form Meckel s cartilage (Fig 331)

The posterior extremities of the pterygoquadrate bar of Meckel s cartilage articulate with each other The intermediate portion of Meckel s cartilage retrogresses and its sheath becomes ligamentous forming the anterior ligament of the malleus and the sphenomandibular ligament. The dorsal portion in contact with the pterygoquadrate cartilage becomes recognizable as the definitive cartilaginous rudiment of the malleus while the ventral portion is involved in the development of the incus (Fig 332)

Later in development two membrane bones are laid down on the outer side of Meckel s cartilage (Fig 332) (1) The ante

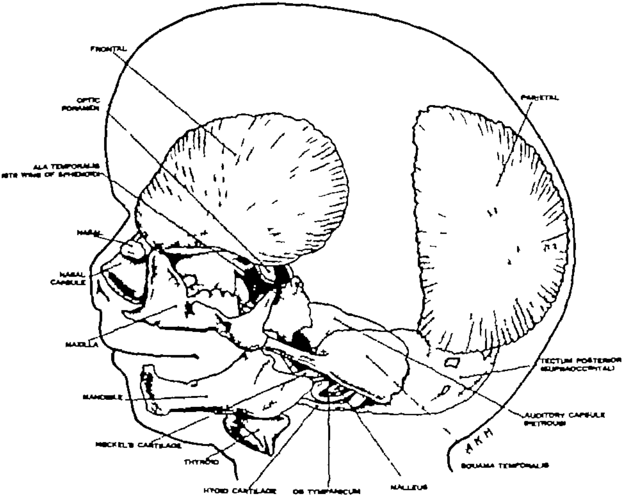

FIG 332 Lateral aspect of a model of the skull of an 80 mm human embryo The chondrocranium is colored blue, the membrane bones, yellow and the ala temporalis green. (Based on Hertwig's model, from Kollmann's Handatlas, 1907)

(Figs. 331 and 332 from W J Hamilton J D Boyd and H W Mossman *Human Embryology* The Williams & Wilkins Co. 1945)

rior of these which appears very early is related to the lateral aspect of the ventral portion of the cartilage and forms the mandible. At first it is a small covering of membrane bone but by growth and extension it soon surrounds Meckel's cartilage, except at its anterior extremity where some endochondral ossification occurs (2) An upward growth forms the ascending ramus at the posterior end of the developing mandible (Fig 333) This portion of the mandible comes into contact with the squamous part of the temporal bone to form the temporomandibular joint, in which a fibrocartilaginous articular disk develops Part of the ramus of the mandible is transformed into cartilage before ossification occurs

In mammals, as in many other vertebrates arches of membrane bone are laid down lateral to the cartilages of the first pharyngeal arch and in the substance of the maxillary and mandible processes In the maxillary processes of each side four such ossification areas form the premaxilla maxilla zygomatic and squamous temporal bones from before backward

The mandible small at birth (Fig 320) is destined to grow both by development of the alveolar processes which accompany the development of the teeth and by bone growth. Bone grows and increases in size by new bone formation upon its ends and in thickness by deposition of layer upon layer to its sides. It is of fundamental importance to understand that there is no interstitial growth in bone increase in length occurs

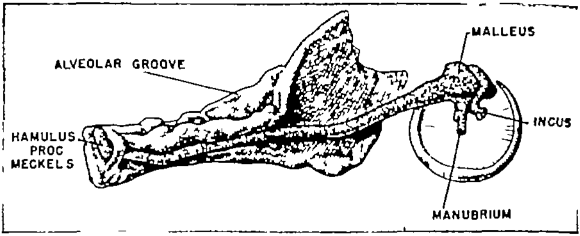

FIG. 333 Mandible, Meckel's cartilage, malleus and incus of a human fetus 80 mm. long (After Kollma Keibel, Franz and Franklin P Mall *Manual of Human Embryology* J B. Lippincott Co.)
(From H H Shapiro, *Maxillofacial Anatomy* J B Lippincott Co. 1954)

by addition to the ends only The central area of bone is inert for it is actively changing its pattern and structure such activity however does not contribute to its length

John Hunter (1835–1857) demonstrated the mode of growth of the mandible he employed the discovery of Duhamel who had studied the growth of bone by feeding madder to animals and applying the principle that madder stains bones a red color The observation that madder a root of a plant, had the property of acting as a vital stain for living bone cells, was described by Belch

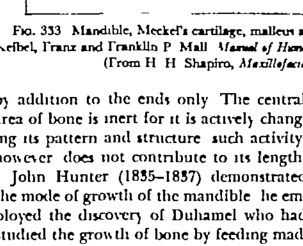

FIG 334 Copy of Hunter s drawing to show the manner in which growth takes place in the mandible The drawings represent two views of the right half of the mandible of a pig which was fed on a madder diet for a month and then for a month on normal diet. The outl ne of the ramus at the end of the madder period is shown by the color (After Keith, 1919)

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growth in length of the mandible He also demonstrated that two events can occur to any given element of bone after it has been laid down either more layers of bone are added to the surface or bone is absorbed at the surface. A local injury to the middle portion of a bone for example to the middle portion of the body of the mandible may interfere with a local increase in thickness, and injury to the growing end may interfere with its increase in length producing deformity Growth changes in the mandible are more complex than those of the long bones because of its shape and because of the presence of teeth Local growth interference following injury may result in a local lack of increase in thickness, and also a disturbance in the formation and eruption of the teeth.

Two types of bone growth occur in the following principal areas of the mandible (1) appositional growth at the posterior border of the ramus, the sigmoid notch the tip of the coronoid process and the alveolar margin and (2) epiphyseal growth at the condyle. Concomitantly with this appositional and epiphyseal growth there occurs a continuous surface remodeling Normal development of the mandible depends upon the co-ordination of the growth activities of the various growth centers Any interference which affects normal growth alters the orderly progression of development and results in mandibular deformity

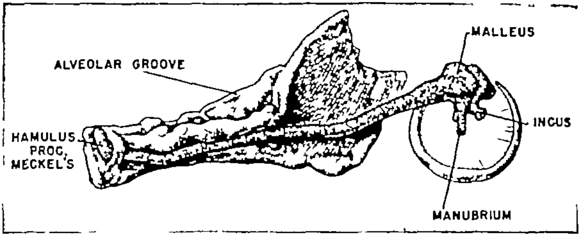
The condyle is an important growth center of the mandible mandibular deformities can often be traced back to early infection or trauma of the condyle. If injury to the condyle occurs early in life the deformity is of greater severity for the effect upon condylar growth activity is greater in the period of maximum condylar growth than after the mandible has reached its full development. Sarnat and Engel (1951) in an experimental study resected the mandibular condyle on one side and bilaterally in young monkeys and observed deformities resulting from the procedure that have been noted in clinical practice.

Growth of the condyle is the result of endochondral ossification in the epiphysis Microscopic examination of human material (Orban 1944 Rushton 1946) revealed chondrogenic, cartilaginous and osseous zones The condyle is capped by a narrow layer of avascular fibrous tissue which contains connective tissue cells and a few cartilage cells The inner layer of this covering is chondrogenic, giving rise to hyalin cartilage cells which form the second or cartilaginous zone Destruction of the cartilage and ossification around the cartilage scaffolding can be seen in the third zone. The cartilage of the head of the mandible is not similar to the epiphyseal cartilage of a long bone for it is not interposed between two bony parts and it is not similar to articular cartilage because the free surface bounding the articular space is covered by fibrous tissue

Postnatal Growth of the Maxilla

Arrested growth of the maxilla and other bones of the middle third of the face are frequently seen in cleft palate conditions Arrested growth has been attributed to early surgery of the region Considerable controversy exists in regard to the suitable age for surgical closure of the palate Investigations employing serial cephalometric roentgenograms have shed considerable light on the problem. Growth of the maxilla appears mostly at the zygomatico-temporal and zygomatico-maxillary sutures, these areas contributing to the antero-inferior growth of the face. In experiments by Gans and Sarnat (1951) using amalgam implants in young monkeys the greatest amount of growth as measured by the space between the amalgam implants, occurred in these suture areas.

In conclusion growth of the bony framework of the face occurs in three ways (1) on its surfaces (2) by replacement of growing cartilage at the epiphyseal area in the con



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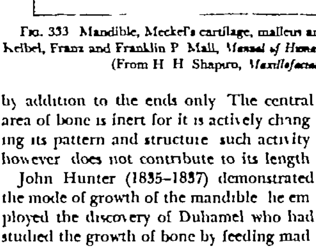

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Two types of bone growth occur in the following principal areas of the mandible (1) appositional growth at the posterior border of the ramus the sigmoid notch the tip of the coronoid process and the alveolar margin and (2) epiphyseal growth at the condyle. Concomitantly with this appositional and epiphyseal growth there occurs a continuous surface remodeling Normal development of the mandible depends upon the co-ordination of the growth activities of the various growth centers. Any interference which affects normal growth alters the orderly progression of development and results in mandibular deformity

The condyle is an important growth center of the mandible mandibular deformities can often be traced back to early infection or trauma of the condyle If injury to the condyle occurs early in life, the deformity is of greater severity for the effect upon condylar growth activity is greater in the period of maximum condylar growth than after the mandible has reached its full development. Sarnat and Engel (1951) in an experimental study resected the mandibular condyle on one side and bilaterally in young monkeys and observed deformities resulting from the procedure that have been noted in clinical practice.

Growth of the condyle is the result of endochondral ossification in the epiphysis. Microscopic examination of human material (Orban 1944 Rushton 1946) revealed chondrogenic, cartilaginous and osseous zones. The condyle is capped by a narrow layer of avascular fibrous tissue which contains connective tissue cells and a few cartilage cells. The inner layer of this covering is chondrogenic, giving rise to hyalin cartilage cells which form the second or cartilaginous zone. Destruction of the cartilage and ossification around the cartilage scaffolding can be seen in the third zone. The cartilage of the head of the mandible is not similar to the epiphyseal cartilage of a long bone for it is not interposed between two bony parts and it is not similar to articular cartilage because the free surface bounding the articular space is covered by fibrous tissue.

Postnatal Growth of the Maxilla

Arrested growth of the maxilla and other bones of the middle third of the face are frequently seen in cleft palate conditions. Arrested growth has been attributed to early surgery of the region Considerable controversy exists in regard to the suitable age for surgical closure of the palate In vestigations employing serial cephalometric roentgenograms have shed considerable light on the problem. Growth of the maxilla appears mostly at the zygomatico-temporal and zygomatico-maxillary sutures these areas contributing to the antero-inferior growth of the face. In experiments by Gans and Sarnat (1951) using amalgam implants in young monkeys the greatest amount of growth as measured by the space between the amalgam implants, occurred in these suture areas.

In conclusion growth of the bony framework of the face occurs in three ways (1) on its surfaces (2) by replacement of growing cartilage at the epiphyseal area in the con

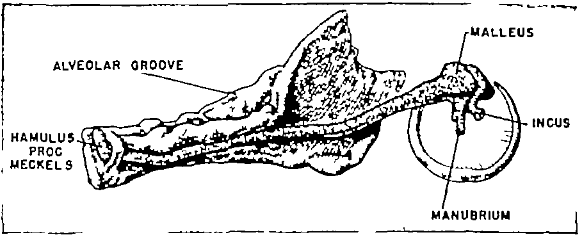


FIG 333 Mandible, Meckel s cartilage, malleus and incus of a human fetus 80 mm. long (After Kollman Keibel Franz and Franklin P Mall, *Manual of Human Embryology* J B. Lippincott Co.)
(From H H Shapiro, *Maxillofacial Anatomy* J B. Lippincott Co., 1954)

by addition to the ends only The central area of bone is inert for it is actively changing its pattern and structure such activity however does not contribute to its length

John Hunter (1835–1837) demonstrated the mode of growth of the mandible he employed the discovery of Duhamel who had studied the growth of bone by feeding madder to animals and applying the principle that madder stains bones a red color The observation that madder a root of a plant had the property of acting as a vital stain for living bone cells, was described by Belcher (1738) and Duhamel (1743) Belcher fed some of his fowls with madder and noted that living bones were stained red by the madder

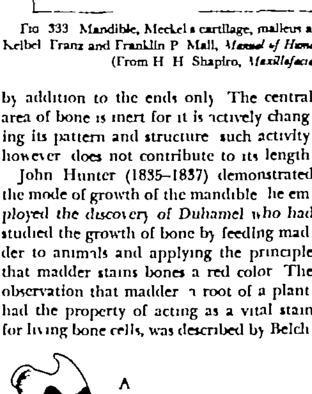


FIG 334 Copy of Hunter s drawing to show the manner in which growth takes place in the mandible The drawings represent two views of the right half of the mandible of a pig which was fed on a madder diet for a month and then for a month on normal diet The outline of the ramus at the end of the madder period is shown by the color (After Keith, 1919)

Hunter fed two young pigs on a madder diet for a month He sacrificed one of the pigs at the end of the month and retained the other for an additional month on ordinary food before sacrificing it Hunter found that the appearance presented by these two bones met his expectations in the most exact manner What had been the condyle and the posterior border of the mandible during the madder period were now included in the substance of the ramus, surrounded by new bone forming the new condyle and a new posterior border of the ramus, which had grown during the period in which the pigs had not received madder The madder stained bone was almost completely removed by absorption from the anterior border of the ramus (Fig 334) Hunter thus noted that the growth of the bone is due to the addition of bone on the extremity of the mandible combined with absorption of bone in other areas (Keith 1919)

Hunter s classical experiments suggest that injury in the growing portion of the mandible in the region of the condyle or excessive pressure produced by forceps at the time of delivery can cause an arrest in the deposition of bone responsible for the

or negative nasal pressure. Leader suggested that this fluctuating air pressure stimulates the nasal mucosa, increases the blood supply and fosters maxillary bone growth

The mandible achieves growth when the entire dentition is formed even if the teeth remain unerupted and impacted Observations made on a child with congenital anodontia from birth to the age of five years showed development within normal limits (Brodie and Sarnat 1942) The mandible remains considerably undersized however in early acquired ankylosis, with masticating muscle function reduced to a minimum

dyle and (3) at the sutures which join the bones of the facial framework.

Factors Influencing Normal Growth of the Facial Skeleton

Among factors influencing maldevelopment of the skeletal framework as the result of traumatic injury are the following: injury to growth centers malunited fractures with displacement of bony fragments loss of muscular activity the blood supply as noted by the increase in size of bone affected by *a hemangioma or the effect of soft tissue* scars.

Developmental malformations of the mandible are often due to direct injury but may also be traced to disease such as osteomyelitis resulting from an injury or from ankylosis of one or both condyles following injury or osteomyelitis, or from condylectomy Simple fracture of the condyle without infection may result in lack of growth Radiation may also arrest growth

Experimental resection of the mandibular condyle produced serious interference with growth of the mandible (Sarnat and Engel 1951) An asymmetrical deformity was produced when one condyle was removed when both condyles were resected a symmetrical growth arrest of the entire mandible occurred The ramus failed to grow vertically when the condyle was removed Ramus growth required an adjustment in the position of the mandible and a new joint was formed anterior to the original one Mandibular function was preserved by the formation of a functional false joint anterior to the original site of the joint These studies reveal that the condyle is an important mandibular growth center and that injury to this area may result in serious developmental malformation

Darwin (1872) conducted experiments to show the effect of muscular activity on the growth of bone He demonstrated that disuse of the ears in rabbits affected almost every suture in the skull. Walkhoff (1905) removed a portion of the left temporal muscle in dogs, discontinuing the attachment to the coronoid process. This resulted in asymmetry of the cranium and also in a bending of the snout to the left.

Washburn (1916) reported cranial asymmetries following unilateral sectioning of the seventh cranial nerve in rats and rabbits, thus affecting the functioning of the facial musculature.

Changes in the form and direction of the *neck and head of the mandibular condyle* resulted from removal of the temporalis muscle (Horowitz and Shapiro 1951). In a more recent study (1955) the same authors found architectural variations in the craniofacial skeleton following unilateral removal of the masseter muscle in the rat, these changes probably resulting from functional imbalance in the remaining masticatory muscles.

Baker (1922) has shown that variation in the masticating power of the teeth produces changes in the symmetry of the skull of animals. It would seem that the development and preservation of normal facial form are important factors in maintaining equilibrium between various muscle groups, and that diseases which influence muscle function may eventually affect the bony contour Dental arch deformities, especially characterized by open bite have been reported by Brown and Losch (1939) in cases of muscular dystrophy with disease of primary muscle origin

The development of the maxilla occurs in a fairly normal fashion in cases of early ankylosis of the tempormandibular joint. The controlling growth factor in the maxilla appears to be the effect of nasal breathing on the pneumatic cavities and blood supply of the bone Leader (1931) showed that the positive pressure rose to plus 1 and the negative pressure fell to minus 5 in breathing through the nose while mouth breathing produced barely ¼ inch positive

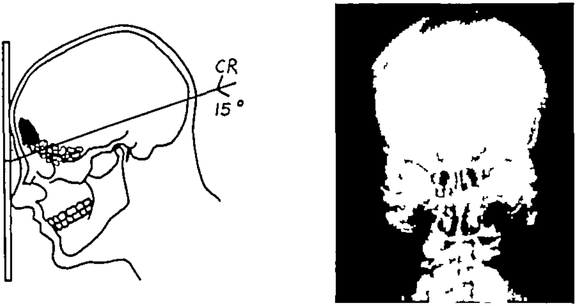


FIG. 335. Caldwell position, postero-anterior view of skull This postero-anterior projection of the facial bones is used to study fractures of the frontal bone, orbital margins, zygomaticofrontal sutures and lateral walls of the maxillary sinuses. The frontal, ethmoidal and the maxillary sinuses are shown in this projection. The petrous ridges should be seen at a level between the lower and middle third of the orbits.

Caldwell Position Postero-Anterior View of the Skull (Fig 335)

This postero-anterior projection of the facial bones is used to study fractures of the frontal bone orbital margins zygomaticofrontal sutures and lateral walls of the maxillary sinuses. The frontal ethmoidal and maxillary sinuses are shown in this projection. The petrous ridges should be seen at a level between the lower and middle third of the orbits.

Positioning

1 Patient seated or prone.

2 The forehead and nose are placed against the Bucky diaphragm.

3 The mid-sagittal plane of the skull is aligned perpendicularly to the mid line of the film.

4 The cantho-meatal line is perpendicular to the film

5 Nasion is centered to the film.

6 The x-ray tube is focused to nasion with a tilt of 15 caudad.

7 Respiration is suspended

Approximate technique

1 60 milliampere seconds

2 78 kilovolts

3 36-inch focal film distance

4 Extension cone

5 Potter Bucky diaphragm

6 Average screen film 8 by 10 inches, lengthwise

Waters Position Postero-Anterior View for the Maxillary Sinuses, Maxilla, Orbits and Zygomatic Arches (Fig 336)

This view is especially helpful in the study of fractures of the maxilla and maxillary sinuses, the orbits (particularly the orbital floor and inferior orbital rim) the zygomatic bones and zygomatic arches. To a lesser extent this projection is helpful in demonstrating fractures of the nasal bones and nasal processes of the maxilla. The petrous ridges should be projected just below the floors of the maxillary sinuses.

Positioning

1 Patient is seated or prone.

2 The mid-sagittal plane of the head is aligned vertically to the mid line of the Potter Bucky diaphragm.

3 The head is rested on the chin with the nasal tip elevated approximately 1.5 cm The upper lip is aligned to the center of the film

4 The x ray tube is focused at right angles

13

ROENTGEN EXAMINATION OF THE FACIAL BONES*

Roentgen examination is indispensable for the diagnosis and treatment of fractures, congenital malformations, or defects of the facial bones.

Adequate roentgen examination determines the presence of fracture and indicates the nature and extent of the fracture and bony displacement. Information derived from the roentgen film when correlated with clinical findings, is an important guide in the management of facial defects the film supplies a permanent preoperative record of bony injury or deformity

Postoperative roentgen studies offer graphic evidence of the proper reduction of displaced fracture fragments or of the plastic correction of other bony defects and indicates bony union at the site of fracture or at the site of plastic surgical repair these are important considerations following the repair of facial fractures and malformations.

Commonly employed roentgen projections and techniques for the general survey and the more localized examination of the facial bones are presented in this chapter for these roentgen views are apt to be most helpful and informative in the diagnosis and management of fractures and other plastic surgical problems of the facial bones.

Technique

1 The Potter Bucky diaphragm is used to obtain better bone detail except with dental and occlusal films and in examination of the nasal bones and mandible.

2. The nasal bones are examined with non-screen technique

3 Average or par-speed screens are used with all of the techniques recommended in this chapter

4 Stereoscopic films can be made where desired especially when right angle views cannot be obtained

5 Planigrams (tomograms) can be made when an especially exhaustive roentgen study is required to determine the presence of fracture or bone defect in the bony walls of the orbits or sinuses or to detect pathological changes in the temporomandibular joints.

6 Immobilization of the head during roentgen examination is mandatory This may be achieved by use of a head clamp or head band or sandbags.

Exposure Factors

The exposure factors given here are approximate and must be adapted to the particular x ray machine employed

Body Position

The patient should be examined in the erect position to detect fluid levels in fractures which involve the paranasal sinuses. Either the erect or recumbent position may be used in other instances.

* Contributed by Dr J Zizmor Roentgenologist Manhattan Eye Ear and Throat Hospital

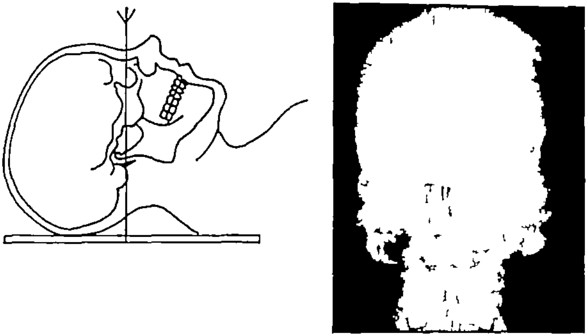


FIG 337 Fronto-occipital anteroposterior projection. When injuries prevent roentgen examination of the facial bones with the patient in the prone or seated postero-anterior position, the following two projections may be used the fronto-occipital antero-posterior projection and the reverse Waters projection.

The fronto-occipital anteroposterior projection offers a good view of the orbits, greater and lesser wings of the sphenoids, the frontal bone, frontal and ethmoidal sinuses, the bony nasal septum, floor of the nose, hard palate, mandible, and upper and lower dental arches.

Reverse Waters Mento-Occipital Position (Fig 338)

The reverse Waters projection gives a view of the facial bones similar to the Waters view except for greater magnification of the facial bones due to increased part film distance. Fractures of the orbits, maxillary sinuses, zygomatic bones and zygomatic arches are well shown.

Positioning:

1 The patient is in the supine position with head resting on the occiput.

2 The mid-sagittal plane of the head is aligned to the mid plane of the cassette.

3 Lambda is centered to the film

4 The x-ray tube is focused in the mid line at an angle of 30 cephalad through the lips to the occiput at its point of contact with the x-ray table or cassette.

5 Respiration is suspended.

Alternative

1 The patient is in the supine position.

2 The chin is elevated to bring the cantho-meatal line to a 120° angle.

3 The lips are centered to the film

4 The tube is focused vertically downward in the mid line through the upper lip to the center of the film.

Approximate technique

1 60 milliampere-seconds

2 86 kilovolts

3 36-inch focal film distance

4 6-inch cone

5 Potter Bucky diaphragm

6 Average screen film 8 by 10 inches, lengthwise

Oblique Orbital—Optic Foramen Position (Fig 339)

This oblique postero-anterior view of the facial bones shows the optic foramen in the lower inferior quadrant of the orbit and demonstrates its relationship to the posterior ethmoidal and sphenoidal sinuses. The lateral wall of the frontal sinuses, vertical plate of the frontal bone and roof and lateral wall of the dependent orbit are well shown. The lateral wall of the opposite

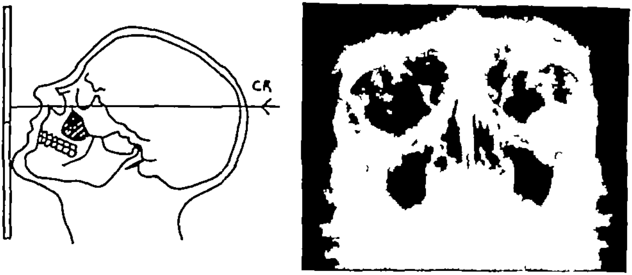


Fig 336. Waters position, postero-anterior view for maxillary sinuses, maxilla, orbits and zygomatic arches. This view is especially helpful in the study of fractures of the maxilla and maxillary sinuses, the orbits (particularly the orbital floor and inferior orbital rim) the zygomatic bones and zygomatic arches. To a lesser extent this projection is helpful in demonstrating fractures of the nasal bones and nasal processes of the maxilla. The petrous ridges should be projected just below the floors of the maxillary sinuses.

to the film and centered to the junction of the upper lip and nose

5 Respiration is suspended

Approximate technique

1 60 milliampere-seconds
2 86 kilovolts
3 36-inch focal film distance
4 Extension cone
5 Potter Bucky diaphragm
6 Average screen film 8 by 10 inches lengthwise

When injuries prevent roentgen examination of the facial bones with the patient in prone or seated postero-anterior position the following two projections may be used (1) the fronto-occipital antero-posterior projection and (2) the reverse Waters projection

Fronto-Occipital Anteroposterior Projection (Fig 337)

This projection gives a good view of the orbits greater and lesser wings of the sphenoids, the frontal bone frontal and ethmoidal sinuses bony nasal septum floor of the nose hard palate mandible and upper and lower dental arches.

Positioning

1 The patient is in the supine position.

2 The mid-sagittal plane of the skull is vertical to the mid line of the cassette or the Bucky diaphragm.

3 The chin is depressed to bring the cantho-meatal line prependicular to the cassette or table top

4 The cassette is centered to the inter pupillary line

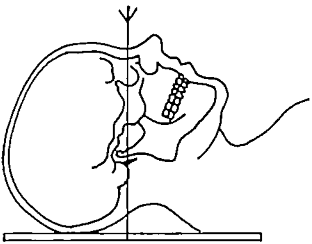
5 The central ray is directed vertically through nasion to the center of the cassette

6 Respiration is suspended.

Approximate technique

1 60 milliampere-seconds
2 80 kilovolts
3 36-inch focal film distance
4 6-inch cone
5 Potter Bucky diaphragm
6 Average screen film 8 by 10 inches, lengthwise

In special cases of injuries to the orbits and maxillary sinuses, the planigraphic roentgen technique may be employed with the fronto-occipital projection to visualize fractures of the orbital floors and maxilla more clearly



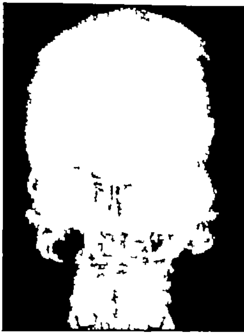


FIG 337 Fronto-occipital anteroposterior projection. When injuries prevent roentgen examination of the facial bones with the patient in the prone or seated postero-anterior position, the following two projections may be used the fronto-occipital antero-posterior projection and the reverse Waters projection

The fronto-occipital anteroposterior projection offers a good view of the orbits, greater and lesser wings of the sphenoids, the frontal bone, frontal and ethmoidal sinuses, the bony nasal septum, floor of the nose, hard palate, mandible, and upper and lower dental arches.

Reverse Waters Mento-Occipital Position (Fig 338)

The reverse Waters projection gives a view of the facial bones similar to the Waters view except for greater magnification of the facial bones due to increased part film distance. Fractures of the orbits, maxillary sinuses, zygomatic bones and zygomatic arches are well shown.

Positioning·

1 The patient is in the supine position with head resting on the occiput.

2. The mid-sagittal plane of the head is aligned to the mid plane of the cassette

3 Lambda is centered to the film.

4 The x ray tube is focused in the mid line at an angle of 30 cephalad through the lips to the occiput at its point of contact with the x ray table or cassette

5 Respiration is suspended.

Alternative

1 The patient is in the supine position.

2. The chin is elevated to bring the cantho-meatal line to a 120 angle

3 The lips are centered to the film.

4 The tube is focused vertically downward in the mid line through the upper lip to the center of the film.

Approximate technique

1 60 milliampere-seconds

2. 86 kilovolts

3 36-inch focal film distance

4 6-inch cone

5 Potter Bucky diaphragm

6 Average screen film, 8 by 10 inches, lengthwise

Oblique Orbital—Optic Foramen Position (Fig 339)

This oblique postero-anterior view of the facial bones shows the optic foramen in the lower inferior quadrant of the orbit and demonstrates its relationship to the posterior ethmoidal and sphenoidal sinuses. The lateral wall of the frontal sinuses, vertical plate of the frontal bone and roof and lateral wall of the dependent orbit are well shown. The lateral wall of the opposite

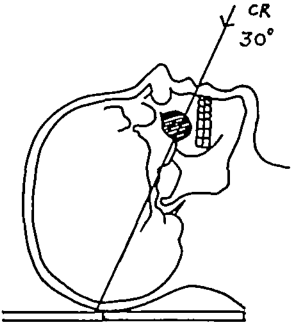
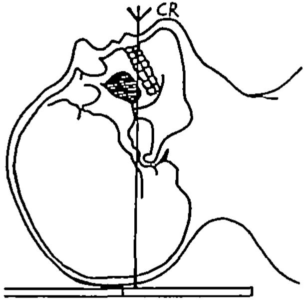


Fig 338. Reverse Waters mento-occipital position. The reverse Waters projection gives a view of the facial bones similar to the Waters view except for greater magnification of the facial bones due to increased part film distance Fractures of the orbits, maxillary sinuses, zygomatic bones and zygomatic arches are well shown.



orbit is clearly defined as viewed through a bright spotlight. The oblique view is helpful in the study of fractures, malformations and tumors of the orbit or optic foramen.

Positioning·

1 The patient is either seated or prone

2. Rest the head on the orbit nose and cheek with the dependent orbit centered to the film

3 Focus the x ray tube through the dependent orbit at an angle of 8 toward the feet

4 Suspend respiration.

Approximate technique

1 60 milliampere-seconds

2. 78 kilovolts

3 36-inch focal film distance

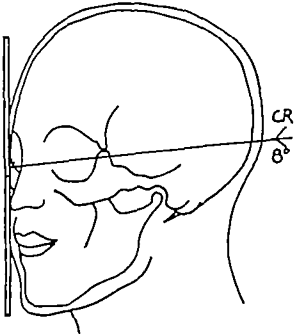
4 Extension cone

5 Potter Bucky diaphragm

6 Average screen film 6½ by 8¼ inches

Underexposed Submentovertex Axial Position for the Zygomatic Arches (Fig 340)

This view shows the zygomatic arches clearly and demonstrates any deformity or



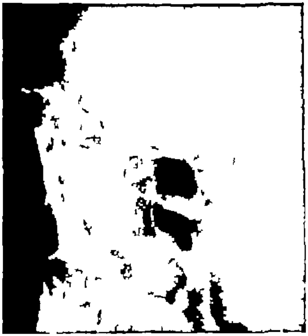
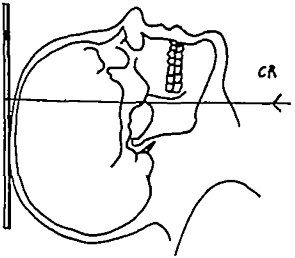


Fig 339 Oblique orbital, optic foramen position. This oblique postero-anterior view of the facial bones shows the optic foramen in the lower inferior quadrant of the orbit and demonstrates its relationship to the posterior ethmoidal and sphenoidal sinuses. The lateral wall of the frontal sinuses, vertical plate of the frontal bone and the roof and lateral wall of the dependent orbit are well shown The lateral wall of the opposite orbit is clearly defined as viewed through a bright spotlight. The oblique view is helpful in the study of fractures, malformations and tumors of the orbit or optic foramen.



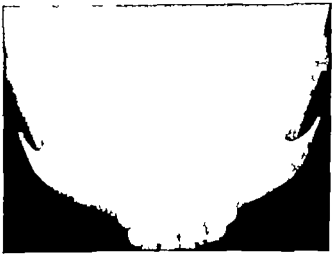


Fig. 340 Underexposed submentovertex axial position for zygomatic arches. This view shows the zygomatic arches clearly and demonstrates any medial or lateral displacement of fracture fragments or deformity

medial or lateral displacement of fracture fragments.

Positioning-

1 The patient may be seated.

2. If the supine position is used, the shoulder should be elevated with pillow or sandbags to obtain maximum extension of the neck.

3 The head, in full extension is rested against the table or upright Bucky on its vertex.

4 The mid-sagittal plane of the skull is aligned vertically to the mid plane of the film.

5 The base line of the skull parallels the plane of the film as closely as possible.

6 The tube is focused mid way between angles of jaw at an angle of 90 to 100° to the base line of the skull so that the central ray is centered to the film.

7 Respiration is suspended.

Approximate technique

1 60 milliampere-seconds

2 60 kilovolts

3 36-inch focal film distance

4 6-inch cone

5 Potter Bucky diaphragm

6 Average screen film 8 by 10 inches

Lateral Profile View of the Face (Fig 341)

This projection which shows the lateral profile of the facial bones and soft tissues of the face, is important for studying fractures of the vertical plate of the frontal bone and under or overdevelopment of the mandible, both preoperatively and postoperatively

Positioning

1 The patient is either seated or in a semiprone position

2 The head is placed in exact lateral position with the dependent zygomatic bone centered to the film and the mid-sagittal plane of the head parallel to the film

3 The central ray is focused perpendicularly to the center of the film and enters the head through the upper zygomatic bone.

4 Respiration is suspended.

Approximate technique

1 60 milliampere-seconds

2 50 kilovolts for soft tissue visualization or 62 kilovolts for bone detail

3 36-inch focal film distance

4 Extension cone

5 Potter Bucky diaphragm

6 Average screen film 8 by 10 inches lengthwise

Nasal Bones—Lateral Views (Fig 342)

Right and left lateral views demonstrate the nasal bones the soft tissues of the nose and the anterior nasal spine of the maxilla in profile Fractures of the nasal bones and anterior nasal spine and fractures of the nasal processes of the maxillae are usually well visualized

Positioning

1 The head is adjusted in a direct lateral

Fig 341 Lateral profile view of face This projection shows the lateral profile of the facial bones and soft tissues of the face It is important in the study of fractures of the vertical plate of the frontal bone and in the study of under or overdevelopment of the mandible both preoperatively and postoperatively

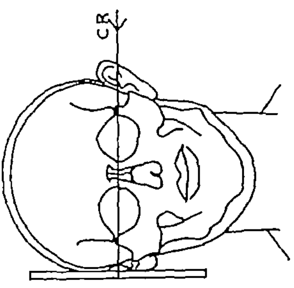


Fig 342. Nasal bones—lateral views. Right and left lateral views demonstrate the nasal bones, the soft tissues of the nose and the anterior nasal spine of the maxilla in profile. Fractures of the nasal bones and anterior nasal spine and fractures of the nasal processes of the maxilla are usually well-visualized

position over a cardboard holder or over an occlusal film which is supported by a sand bag The occlusal film is immediately underneath the nose and in contact with it.

2. The tube is focused centrally through the bridge of the nose at right angles to the plane of the film.

3 Right and left lateral views are always taken.

4 Respiration is suspended

Approximate technique

1 50 milliampere-seconds
2. 30 kilovolts
3 30-inch focal film distance
4 3-inch cone
5 Non-screen cardboard or occlusal film

Nasal Bones—Supero-Inferior Projection (Fig 343)

This axial supero-inferior view of the nasal bones may reveal fractures of the nasal bones and medial or lateral displacement of the bony fragments which are not demonstrated on lateral views. Only those portions of the nasal bones which project anterior to the line between the glabella and the upper incisor teeth are demonstrated in the axial projections. This view is, therefore not helpful in the examination of children or adults who have relatively small or depressed nasal bones in relation to projecting upper teeth or a projecting forehead.

Positioning:

1 The patient is in a supine or seated position

2. The occlusal film is inserted into the mouth just far enough to enable the patient to hold it between the anterior teeth

3 The central ray is focused downward in the mid line tangential to the forehead through the root of the nose at an angle of 90° to 100 to the plane of the occlusal film

Approximate technique

1 60 milliampere-seconds
2. 75 kilovolts
3 30-inch distance
4 3 inch extension cone
5 Occlusal non screen film

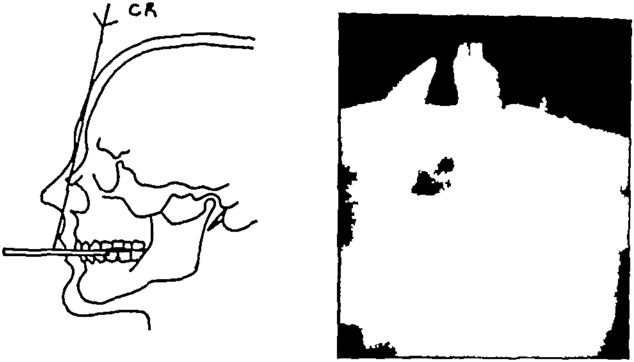


Fig 343 Nasal bones, superoinferior projection. This axial superoinferior view of the nasal bones may reveal fractures of the nasal bones and medial or lateral displacement of the bony fragments which are not demonstrated on lateral views. Only those portions of the nasal bones which project anterior to the line between the glabella and the upper incisor teeth can be demonstrated in the axial projections. This view is therefore not helpful in the examination of children or adults having relatively small or depressed nasal bones in relation to projecting upper teeth or a projecting forehead.

Supero-Inferior Occlusal Views of the Hard Palate

These projections afford vertical axial or obliquely supero-inferior occlusal views of the palatine processes of the maxilla the alveolar processes and the upper dental arch Fractures of the hard palate cysts or bony malformations or defects are well visualized The x ray tube is focused and angled to demonstrate the area of interest.

Supero-Inferior Central Occlusal View of the Hard Palate (Fig 344)

Positioning

1 The patient may be in a supine or seated position

2. The occlusal film is placed as far as possible into the mouth

3 The patient closes the mouth holding the film gently

4 The central ray is focused in the mid sagittal plane perpendicularly through the vertex between the zygomatic prominences to the center of the film

5 Respiration is suspended

Approximate technique

1 60 milliampere-seconds
2. 75 kilovolts
3 30-inch distance
4 3 inch extension cone
5 Occlusal non-screen film

Supero-Inferior Anterior Occlusal View of the Hard Palate (Fig 345)

This projection demonstrates the anterior part of the hard palate and alveolar processes. Better bony detail of the hard palate is obtained than in the previous view because the obliquely focused central ray penetrates soft tissues only on its way to the hard palate This view is routinely used along with the preceding view to demonstrate the bony defect in the cleft palate

Positioning

1 The patient may be either in the supine or seated position.

2 The central ray is focused in the mid

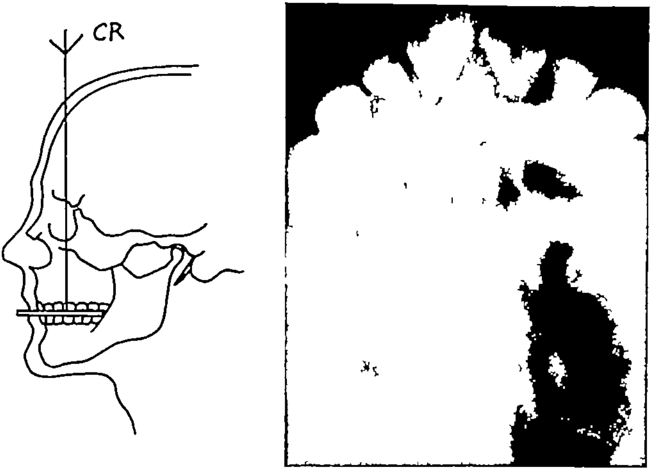


Fig 344 Superoinferior central occlusal view of hard palate

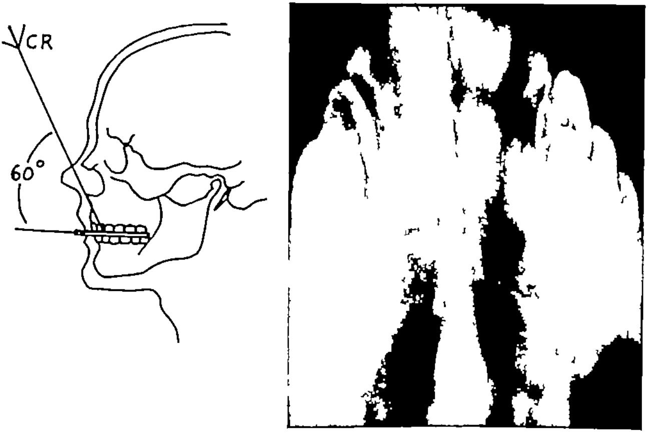


Fig 345 Superoinferior anterior occlusal view of hard palate. This projection demonstrates the anterior part of the hard palate and alveolar processes. Better bony detail of the hard palate is obtained than on the previous view because the obliquely focused central ray penetrates soft tissues only on its way to the hard palate. This view is routinely used along with the preceding view to demonstrate the bony defect in cleft palate.

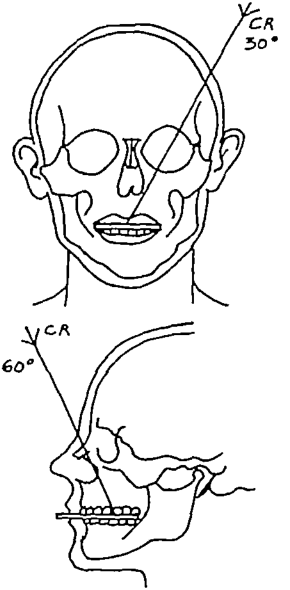


FIG 346. Oblique superoinferior posterior occlusal view of hard palate. This projection demonstrates the posterior portion of the hard palate and laterally its alveolar processes and teeth.

sagittal plane through the tip of the nose at an angle of 60 caudad to the occlusal plane.

3 Respiration is suspended.

Approximate technique

1 30 milliampere-seconds
2 75 kilovolts
3 30-inch distance
4 3-inch extension cone
5 Occlusal non-screen film

Oblique Supero-Inferior Posterior Occlusal View of the Hard Palate (Fig 346)

This projection demonstrates the posterior portion of the hard palate unilaterally the alveolar processes and the teeth

Positioning

1 The patient is seated or in the supine position.

2. The x ray tube is focused to the bicuspid area of the alveolar process at an angle of 60 caudad to the occlusal plane and at an angle of 30 to the mid-sagittal plane of the skull

3 Respiration is suspended

Approximate technique

1 30 milliampere-seconds
2. 75 kilovolts
3 30-inch distance
4 3-inch extension cone
5 Occlusal non-screen film

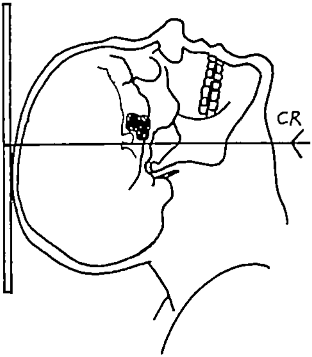


FIG 347 Submentovertex position

Axial Views of the Mandible and Base of the Skull

These projections permit a survey of the mandible, the base of the skull and its foramina, petrous pyramids sphenoidal posterior ethmoidal maxillary sinuses and bony nasal septum

Submentovertex Position (Fig 347)

Positioning·

1 With the patient seated, the head is fully extended and the vertex is placed in contact with the Potter Bucky diaphragm

2 The mid-sagittal plane of the skull is aligned perpendicularly to the mid line of the film.

3 The base line of the skull should parallel the plane of the film as closely as possible.

4 If the supine position is used the shoulders are elevated on pillows or sand bags to permit maximum backward extension of the head.

5 The tube is directed in the mid line at an angle of 90 to 100° to the cantho-meatal line mid way between the angles of the jaw

6 The film is centered to the central ray

7 Respiration is suspended.

Approximate technique

1 60 milliampere-seconds

2 90 kilovolts

3 30-inch focal film distance

4 Extension cone

5 Potter Bucky diaphragm

6 8 by 10 or 10 by 12 inches average screen film

Vertico-Submental Position for the Base of the Skull (Fig 348)

Positioning·

1 With the patient prone the head is rested on the fully extended chin

2 The mid-sagittal plane of the skull is aligned perpendicularly to the mid line of the film

3 The cantho-meatal line of the skull is placed as nearly parallel to the film as possible.

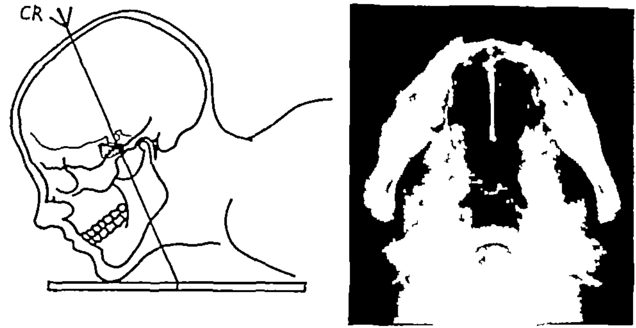


Fig 348. Vertico-submental position for base of skull

4 The x ray tube is centered in the mid line between the angles of the jaw and inclined toward the feet at an angle of 100 *to the cantho-meatal line.*

5 The film is centered to the central ray

6 Respiration is suspended

Approximate technique

1 60 milliampere-seconds

2. 90 kilovolts

3 30-inch focal film distance

4 Extension cone

5 Potter Bucky diaphragm

6 8 by 10 or 10 by 12 inches average screen film

Occlusal Infero-Superior Views of the Mandible

Infero-superior axial views of the mandibular body symphysis and lower alveolar processes and teeth reveal medial or lateral bony displacement in mandibular fractures. This view usually affords good bony detail

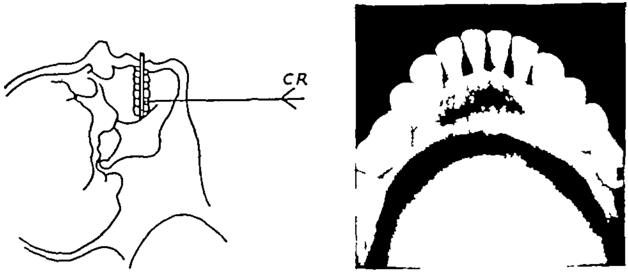


Fig 349 Right angle infero-superior occlusal view of mandible

and is, therefore helpful in the study of neoplasm, malformations, cysts, defects and osteomyelitis of the mandible.

Right Angle Infero-Superior Occlusal View of the Mandible (Fig 349)

Positioning:

1 The patient may be seated or in the supine position with shoulders elevated on sandbags or pillows.

2 The occlusal film is placed as far into the mouth as possible and the patient is instructed to hold the film by closing the mouth gently

3 The head is extended backward with the chin fully elevated.

4 The mid-sagittal plane of the head is vertical.

5 The x ray tube is focused to the submental region behind the symphysis at right angles to the film in the mid sagittal plane of the head.

6 Respiration is suspended.

Approximate technique

1 30 milliampere-seconds

2 75 kilovolts

3 30-inch distance

4 3-inch cone

5 Occlusal non-screen film

Occlusal Infero-Superior Oblique View for the Mental Symphysis (Fig 350)

This view reveals the symphysis menti and the incisor and canine teeth and their alveolar processes with excellent bone detail

Positioning:

1 The patient is seated.

2 The head is extended backward The mid-sagittal plane of the head is vertical

3 The occlusal plane is at an angle of 60 to the horizontal.

4 The x ray tube is focused horizontally through the symphysis of the mandible.

5 Respiration is suspended.

Approximate technique

1 30 milliampere seconds

2 85 kilovolts

3 30-inch distance

4 3 inch cone

5 Occlusal non-screen film

Oblique Supero-Inferior Submental View of the Mandibular Symphysis (Fig 351)

Positioning

1 The patient is seated and bent forward over the x ray table.

2 The chin is rested over a sandbag

Fig 350. Occlusal infero-superior oblique view for the mental symphysis. This view reveals the mental symphysis menti and the incisor and canine teeth and their alveolar processes with excellent bone detail.

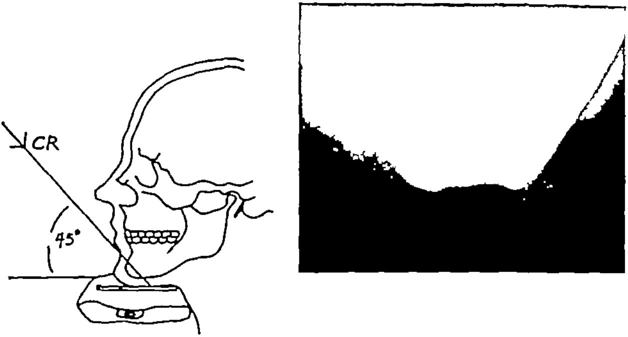


Fig 351 Oblique supero-inferior submental view of mandibular symphysis

3 An occlusal film is centered under the chin

4 The mid-sagittal plane of the head is vertical

5 The x ray tube is focused supero-inferiorly through the symphysis menti at an angle of 45 to the film

6 Respiration is suspended

Approximate technique

1 30 milliampere-seconds

2 85 kilovolts

3 30-inch distance

4 3-inch cone

5 Occlusal non-screen film

Oblique Lateral Views of the Mandible

These projections are employed routinely in the study of fractures, acquired or congenital malformations, cysts, tumors or osteomyelitis of the mandible

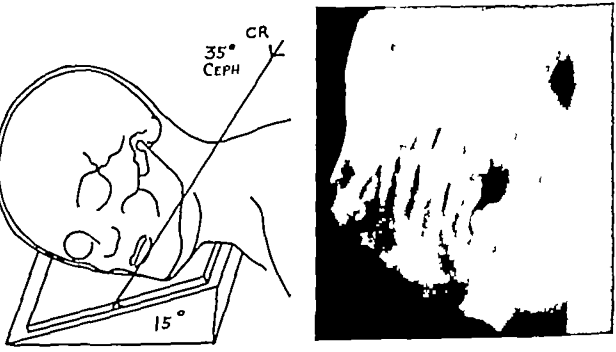


Fig 352 Body of mandible

The Body of the Mandible (Fig 352)

This projection demonstrates the body of the mandible the angle and most of the mandibular ramus on one side.

Positioning

1 The patient is in a prone position

2 The cassette is placed on a 15 angle block.

3 With the chin extended the side of the jaw to be radiographed is placed on the cassette with the occlusal plane aligned to the transverse mid line of the film

4 The mid point of the mandibular body is aligned to the vertical mid line of the film

5 The x-ray tube is focused to the center of the cassette at an angle of 35 cephalad.

6 Respiration is suspended.

Approximate technique

1 10 milliampere-seconds

2 64 kilovolts

3 36-inch distance

4 6-inch cone

5 Average screen film 8 by 10 inches, non-Bucky technique

Ramus of the Mandible (Fig 353)

This is a posteriorly directed oblique lateral view to reveal more of the ramus and mandibular condyle condylar and coronoid processes. The body of the mandible is also well seen.

Positioning

1 The patient is in the prone position

2 The cassette is placed on a 15° angle block.

3 With the chin extended the side of the mandible to be radiographed is placed on the cassette

4 The mid point of the dependent mandibular ramus is centered to the mid point of the cassette

5 The x ray tube is focused 35 cephalad and 10 posteriorly through the mid point of the cassette

6 Respiration is suspended.

Approximate technique

1 10 milliampere-seconds

2 64 kilovolts

3 36-inch distance

4 6-inch cone

5 Average screen 8 by 10 inches, non Bucky technique

Symphysis of the Mandible (Fig 354)

This is an anteriorly directed oblique lateral view of the symphysis of the mandible, the region of the mental foramen and

Fig 353. Ramus of mandible

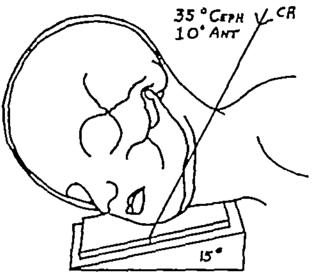


Fig 354 Symphysis of mandible. This is an anteriorly directed oblique lateral view of the symphysis of the mandible, the region of the mental foramen and body of the mandible The ramus is partly visualized

the body of the mandible. The ramus is partly visualized.

Positioning·

1 The patient is in the prone position

2. The cassette is placed transversely on 15 angle block.

3 The chin is extended.

4 The side of the mandible to be radiographed is placed on the cassette

5 The jaw is rested on the anterior aspect of the mandibular body in the area of the mental foramen

6 The mental foramen is aligned at the mid point of the cassette.

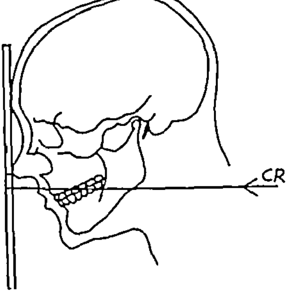


Fig 355 Postero-antero view of mandible This view demonstrates the symphysis body and rami of the mandible the condyloid and coronoid processes and the temporo-mandibular joints This projection may reveal medial or lateral displacement of fracture fragments and asymmetry of development of the mandible

7 The x ray tube is focused 35 cephalad and 10 anteriorly to the center of the cassette.

8. Respiration is suspended.

Approximate technique

1 10 milliampere-seconds

2 64 kilovolts

3 36-inch distance

4 6-inch cone

5 Average screen film 8 by 10 inches, non Bucky technique

Postero-Anterior View of the Mandible (Fig 355)

This view demonstrates the symphysis body and rami of the mandible the condyloid and coronoid processes and the temporomandibular joints. This projection may reveal medial or lateral displacement of fracture fragments and asymmetry of development of the mandible.

Positioning

1 The patient may be seated or in the prone position.

2. The head is rested on the forehead and nose with the mouth aligned to the mid point of the cassette.

3 The mid-sagittal plane of the head is aligned vertically to the mid line of the film.

4 The x-ray tube is focused at right angles to the cassette and centered through the mouth.

5 Respiration is suspended.

Approximate technique

1 60 milliampere-seconds

2 75 kilovolts

3 36-inch distance

4 6-inch cone

5 Potter Bucky diaphragm

6 8 by 10 inch average screen film

Oblique Anteroposterior Fronto-Occipital View of the Temporomandibular Joints (Fig 356)

This view demonstrates the temporomandibular joints simultaneously in an anteroposterior view The mandibular condyles, temporal articular fossae, the right and left petrous bones and internal auditory canals, the occipital bone, posterior cranial fossa and foramen magnum are well visualized

Positioning

1 The patient is in the supine position

2. The head rests on a Potter Bucky diaphragm which is inclined 35 caudad.

3 The mid-sagittal plane of the skull is aligned vertically to the mid plane of the cassette.

4 The *external auditory meati* are aligned to the transverse mid line of the cassette

5 The chin is depressed.

6 The base line of the skull is vertical to the cassette

7 The x ray tube is focused vertically in the mid line through the frontal bone and foramen magnum mid way between the external auditory meati

8 If the Bucky is not tilted 35 toward the feet the x ray tube may be focused instead at a 35 angle toward the feet through the frontal bone and foramen magnum mid way between the temporomandibular joints.

9 The coronal plane of the external auditory canals is aligned between the upper and middle thirds of the cassette.

10 Respiration is suspended.

Approximate technique

1 60 milliampere-seconds

2. 80 kilovolts

3 36-inch distance

4 6-inch cone

5 Average screen film Potter Bucky diaphragm

Focal Oblique Lateral Views of the Temporomandibular Joints (Fig 357)

The temporomandibular joints are examined in the open and closed mouth positions. The closed mouth view demonstrates the temporomandibular joint, the relation of the mandibular condyle to the fossa and the width of the joint cartilage. The open mouth view shows the extent of forward

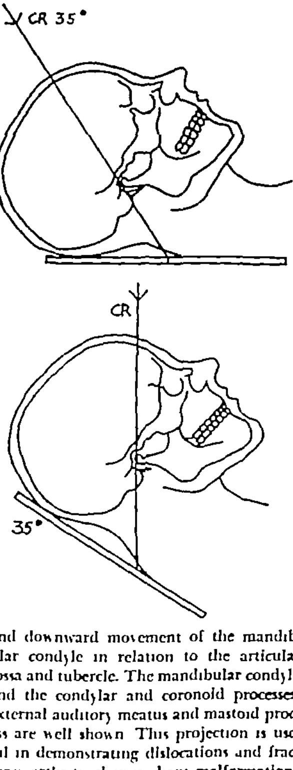


FIG 356. Oblique anteroposterior fronto-occipital view of temporomandibular joints. This view demonstrates the temporomandibular joints simultaneously in an anteroposterior view. The mandibular condyles, temporal articular fossae, the right and left petrous bones and internal auditory canals, the occipital bone, posterior cranial fossa and foramen magnum are well visualized.

and downward movement of the mandibular condyle in relation to the articular fossa and tubercle. The mandibular condyle and the condylar and coronoid processes, external auditory meatus and mastoid process are well shown. This projection is useful in demonstrating dislocations and fractures, arthritic changes, bony malformations and impairment of motion in the temporomandibular joint.

Positioning:

1 The patient is in the prone position.

2 The head is rested on the true lateral position on a cassette changing tunnel.

3 Center the dependent temporomandibular joint to the center of the film.

4 Focus the x ray tube at an angle of 25 caudad through the center of the film.

5 Make one exposure with the mouth closed.

6 Shift the cassette and make a second exposure with the mouth wide open (a cork may be wedged between the upper and lower incisor teeth to stabilize the open mouth position.

7 Respiration is suspended.

Approximate technique

1 30 milliampere-seconds

2 60 kilovolts

3 30 inch distance

4 3 inch extension cone fully extended

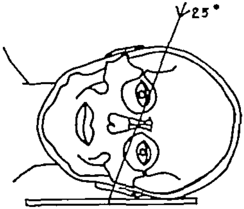


Fig 357 Focal oblique lateral views of temporomandibular joints. The temporomandibular joints are examined in the open and closed mouth positions. The closed mouth view demonstrates the temporomandibular joint, the relation of the mandibular condyle to the fossa and the width of the joint cartilage. The open mouth view shows the extent of forward and downward movement of the mandibular condyle with relation to the articular fossa and tubercle. The mandibular condyle and the condylar and coronoid processes, external auditory meatus and mastoid process are well shown. This projection is useful in demonstrating dislocations and fractures, arthritic changes, bony malformations and impairment of motion in the temporomandibular joint.

5 Average screen film non Bucky technique

Occasionally a direct lateral planigraphic study of the temporomandibular joint may be used if greater roentgen detail is desired.

Mayer View (Fig 358)

This projection gives a unilateral superoinferior view of the temporomandibular joint external auditory canal mastoid process and petrous pyramid. The view is helpful in the study of fractures of the condylar process to show medial or lateral displacement of the bony fragments, in the study of developmental abnormalities and malformations of the temporomandibular joint and the external auditory canal The Mayer view is particularly helpful in the study of bony atresia of the external auditory canal for it reveals the lack of development of an aerated external canal and the relative posterior displacement of the temporomandibular joint.

Positioning

1 The patient is in the supine position

2. The chin is depressed.

3 The head is inclined toward the side under study to bring the mid-sagittal plane of the skull to a 45 angle.

4 The dependent external auditory canal is placed between the upper and middle thirds of the cassette.

5 The outer edge of the cassette is elevated 10 by a sandbag

6 A 3-inch extension cone is fully extended and tilted 45 caudad.

7 The central ray enters the head above the supraorbital ridge of the opposite side and is directed to the dependent external auditory canal

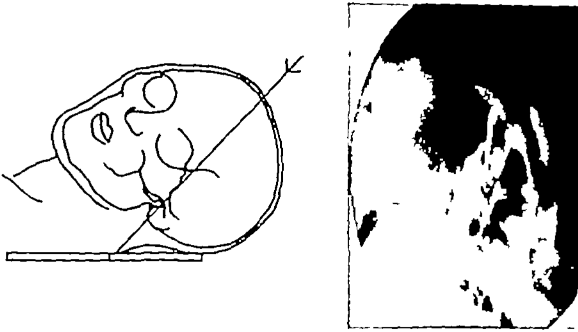


FIG 358 Mayer view This projection gives a unilateral superoinferior view of the temporomandibular joint, external auditory canal, mastoid and petrous. This view is helpful in the study of fractures of the condylar process to show medial or lateral displacement of the bony fragments In the study of developmental abnormalities and malformation of the temporomandibular joint and of the external auditory canal. The Mayer view is particularly helpful in the study of bony atresia of the external auditory canal in that it reveals quite clearly the lack of development of an aerated external canal and the relative posterior displacement of the temporomandibular joint.

8. The extension cone is in contact with the patient's head.

9 Respiration is suspended.

Approximate technique

1 100 milliampere-seconds
2 56 kilovolts
3 3-inch extension cone fully extended
4 Average speed screens

With Bucky technique

1 120 milliampere-seconds
2 82 kilovolts
3 3 inch extension cone fully extended
4 Average screen film

Conclusions

This presentation of the roentgen examination of the facial bones serves as a brief outline of some of the helpful and commonly used roentgen projections. There are many other important and useful roentgen projections for the study of fractures and abnormalities of the facial bones which can not be included in this brief outline. For more detailed and comprehensive information on this subject, the interested student is referred to the appended bibliography

In closing this chapter on the roentgen study of the facial bones, it would be appropriate to stress the importance of proper roentgen examination of the patient in the intelligent interpretation of roentgen films and ultimately in the correct radiological diagnosis.

The most valuable roentgen interpretations are obtained when the plastic surgeon and radiologist confer with each other about the patient's relevant clinical history physical findings, laboratory data and previous history of surgical procedures. If a personal conference is not possible this information should be supplied to the radiologist either by telephone or in writing on the x ray request sheet Such clinical information is of utmost importance in determining the type of roentgen examina

tion to be performed and in evaluating the roentgen film findings. Correlation of the clinical history and pertinent physical and laboratory data with the roentgen findings are most apt to lead to correct diagnosis and proper management of the patient.

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14

INTRODUCTION TO RECONSTRUCTIVE SURGERY OF THE FACE

The purpose of reconstructive surgery of the face is the restoration of function and appearance. If the deformity resulting from injury is of relatively minor degree, such as that resulting from inaccurate adjustment of tissue or malunited fracture good results are achieved in many cases. If the deformity is a major one accompanied by loss of soft tissue or bone the appearance of the face cannot always be restored to that existing before the injury but a great deal of improvement can be achieved.

The operative risk has been diminished by progress in surgical techniques, anesthesia postoperative management and the advent of antibiotics. Surgeons who were frequently saddened in the past by the breakdown of operative sites after painstaking surgery were loathe to expose their patients to the dangers of elective operative *procedures solely for the purpose of im*proving the facial appearance

Many advances have been made in the treatment of deformities during recent years. Both patient and surgeon have become more critical of the final result the aim is always toward greater refinement of technique

The operative procedures outlined in this book for the repair of deformities of the face are perhaps oversimplified for the sake of clarity It should be understood that each case is an individual problem requiring special consideration Since each case presents specific and variable problems, the classification of facial deformities into precisely defined groups is not possible. The condition of the defect and that of the surrounding tissues must be evaluated and the choice of corrective surgery made the simplest procedure should be favored for the risk of failure is lessened and the final result is usually better than when complicated procedures are employed

DIAGNOSIS

Clinical Examination

Correct diagnosis is an essential requisite of successful reconstructive surgery Examination must be thorough and repeated in order to decide upon the amount and type of reconstruction required to correct the deformity

The extent of soft tissue damage is usually evaluated by direct inspection The scars may be disfiguring because of their width the texture of the scar contrasting with that of the surrounding normal skin or because of pigmentation resulting from imbedded foreign particles. The scar may cause a contracture which exerts a pull upon more distant soft tissues or contrac*tion of the healing wound may* cause the main deformity Gross distortion of the face is obvious, as for example displacement or loss of the underlying bony structure such as a depression of the frontal bone deviation of the nose or deviation of

the mandible due to fracture Inspection should also be made of the oral cavity the nasal cavities the conjunctival sac and eyeball, the external auditory canal and the tympanum

Palpation often verifies the findings made by direct inspection The hard or soft texture of scars may be felt. Examination of the underlying bony structure reveals the extent of displacement or loss of bone Abnormal mobility may be felt in cases of non union and the extent of the displacement of malunited fragments may be defined In some cases, palpation may assist in defining the position of the nasal septum in relation to the external nasal structures. Palpation is also an important means of detecting tactile sensations to define areas of anesthesia or hypoesthesia due to injury of the sensory nerves of the face.

The face should be examined in repose and also during expressive movements. This examination will reveal paralysis in facial nerve injury and will also disclose types of deformities such as scars which may become manifest when the muscles of expression contract particularly when the scars cross the lines of facial expression

Photographs and Casts

Photographs record the patient's initial condition are valuable documentary records of the various phases of treatment, and are of assistance in studying the deformity and planning the operative procedures Clinical photographs should be standardized to be of value A good method is to orient the head to the Frankfurt plane (Fig 359) a horizontal line is drawn on the ground-glass plate of the camera and the head placed so that the Frankfurt line is parallel to the line on the plate

Color transparencies and motion pictures afford excellent records of the patient's condition and progress, and provide valuable teaching documents. Casts of the face are also helpful in planning reconstruction of the facial framework. A preliminary roentgenographic examination is an indispensable step in the preoperative study of deformities which involve the skeletal framework. Plaster casts of the dentition are essential for diagnosing the degree of dental malocclusion and planning the treatment.

Anthropometric Points of the Face

Physical anthropologists employ methods of measurement which permit determination of significant likenesses and differences between individuals and races These standardized measurements are useful when attempting to restore the structure and contour of the deformed face Among the commonly employed anthropometric points are trichion the mid point at the hairline on the forehead nasion the most anterior point in the mid-line of the frontonasal suture subnasale the point beneath the nasal spine where the nasal columella merges with the upper lip in the mid-sagittal plane and gnathion the lowest median point of the mandible The mid-sagittal line a vertical line passing through these four points, divides the face into halves (Fig 359*A* *B*) Horizontal lines passing through the same points divide the face into three areas (Fig 359*C* *D*) Tragion is the notch immediately above the tragus of the ear orbitale is the lowest point on the infraorbital margin the Frankfurt horizontal passes through these points.

Measurements of facial dimensions are taken according to three planes vertical (facial length) frontal (facial width) and sagittal (facial depth) (Fig 359*D*) Facial width is obtained by measuring the distance between the most prominent points on the zygomatic bones Facial depth is determined by measuring the distance from the external auditory canal to various points such as nasion subnasale and gnathion The distance between gnathion and gonion tip of the angle of the jaw determines the length of the body of the mandible the distance from nasion to the tip of the nose equals the length of the nose.

14

INTRODUCTION TO RECONSTRUCTIVE SURGERY OF THE FACE

The purpose of reconstructive surgery of the face is the restoration of function and appearance. If the deformity resulting from injury is of relatively minor degree such as that resulting from inaccurate adjustment of tissue or malunited fracture, good results are achieved in many cases. If the deformity is a major one, accompanied by loss of soft tissue or bone the appearance of the face cannot always be restored to that existing before the injury but a great deal of improvement can be achieved.

The operative risk has been diminished by progress in surgical techniques anesthesia postoperative management and the advent of antibiotics. Surgeons who were frequently saddened in the past by the breakdown of operative sites after painstaking surgery were loathe to expose their patients to the dangers of elective operative procedures solely for the purpose of improving the facial appearance.

Many advances have been made in the treatment of deformities during recent years. Both patient and surgeon have become more critical of the final result the aim is always toward greater refinement of technique

The operative procedures outlined in this book for the repair of deformities of the face are perhaps oversimplified for the sake of clarity It should be understood that each case is an individual problem requiring special consideration. Since each case presents specific and variable problems, the classification of facial deformities into precisely defined groups is not possible The condition of the defect and that of the surrounding tissues must be evaluated and the choice of corrective surgery made· the simplest procedure should be favored, for the risk of failure is lessened and the final result is usually better than when complicated procedures are employed

DIAGNOSIS

Clinical Examination

Correct diagnosis is an essential requisite of successful reconstructive surgery Examination must be thorough and repeated in order to decide upon the amount and type of reconstruction required to correct the deformity

The extent of soft tissue damage is usually evaluated by direct inspection The scars may be disfiguring because of their width the texture of the scar contrasting with that of the surrounding normal skin or because of pigmentation resulting from imbedded foreign particles. The scar may cause a contracture which exerts a pull upon more distant soft tissues or contraction of the healing wound may cause the main deformity Gross distortion of the face is obvious, as for example, displacement or loss of the underlying bony structure such as a depression of the frontal bone deviation of the nose or deviation of

the mandible due to fracture Inspection should also be made of the oral cavity the nasal cavities, the conjunctival sac and eye ball the external auditory canal and the tympanum

Palpation often verifies the findings made by direct inspection The hard or soft tex ture of scars may be felt. Examination of the underlying bony structure reveals the extent of displacement or loss of bone Abnormal mobility may be felt in cases of non union and the extent of the displacement of malunited fragments may be defined. In some cases, palpation may assist in defining the position of the nasal septum in relation to the external nasal structures Palpation is also an important means of detecting tactile sensations to define areas of anesthesia or hypoesthesia due to injury of the sensory nerves of the face.

The face should be examined in repose and also during expressive movements. This examination will reveal paralysis in facial nerve injury and will also disclose types of deformities such as scars, which may become manifest when the muscles of expression contract particularly when the scars cross the lines of facial expression

Photographs and Casts

Photographs record the patient's initial condition are valuable documentary records of the various phases of treatment, and are of assistance in studying the deformity and planning the operative procedures Clinical photographs should be standardized to be of value. A good method is to orient the head to the Frankfurt plane (Fig 359) a horizontal line is drawn on the ground-glass plate of the camera and the head placed so that the Frankfurt line is parallel to the line on the plate

Color transparencies and motion pictures afford excellent records of the patient's condition and progress, and provide valuable teaching documents Casts of the face are also helpful in planning reconstruction of the facial framework. A preliminary roentgenographic examination is an indispensable step in the preoperative study of deformities which involve the skeletal framework. Plaster casts of the dentition are essential for diagnosing the degree of dental malocclusion and planning the treatment.

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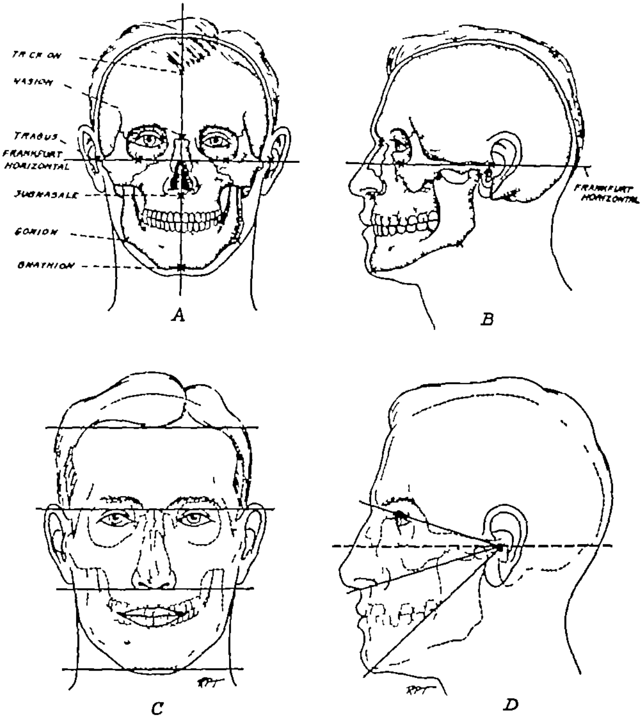

Fig 359 Anthropometry of the face

A. Anthropometric landmarks.
B. The Frankfurt horizontal.
C. Horizontal lines dividing the face into thirds.
D. Lines showing dimensions in depth.

(After Ashley Montagu and Hellman.)

Horizontal lines passing through trichion nasion subnasale and menton divide the physiognomic face into three thirds, theoretically of equal height in practice *however each third of the face differs in size from the others.*

Interpretation of the Deformity

Deformity resulting from accident may be minor or at least appear to be to the surgeon or to an impartial observer To *the patient however the deformity may* assume a magnitude out of all proportion

to reality One of the main purposes of reconstructive treatment is to restore the mental health of the patient, thus permitting a return to active social participation The psychological trauma suffered by the patient may be related to the injury and the circumstances of the accident or may be due to remarks of relatives or friends. One of the distressing aspects of this type of surgery is that the successful repair of even major traumatic deformities is not necessarily followed by a cure. Deep-seated psychological disturbances may remain

In major deformities, physical diagnosis is more obvious but in many serious disfigurements, despite the great progress made in surgery the marked improvement achieved does not necessarily completely restore the physical appearance of the patient. The severity of the psychological disturbance is not necessarily related to the severity of the deformity nor is it directly proportional to the degree of improvement brought about by surgery Cultural aspects complicate this picture. A classical example is the scar resulting from the Heidelberg duels, considered an emblem of an individual's manliness rather than a disfigurement

The Apparent Defect the True Defect

In distortions due to scarring following soft tissue loss, the loosely attached tissue is pulled toward the more tightly bound tissue consequently evaluation of the extent of the deformity is often difficult. The extent of the scarred area over the defect does not represent the true defect but the apparent defect. The true defect is revealed only after the scar is excised and the adjacent tissues have resumed their normal relationships (Fig 360*A* *B*) In preparing flaps for the repair of a defect it is important to evaluate the size of the true defect preoperatively diagnosis of the true defect can often be made by comparison with the normal side and by plotting the true defect on the normal side

The unaffected side of the face serves as a guide if the deformity is unilateral Approximate measurements can be made by comparing the relation of soft tissues to landmarks first on the affected side of the face and then on the unaffected side. For example in a defect of the ala of the nose, the tip of the nose may be twisted to the affected side because of scar contracture The true defect can be estimated by measuring the length of the ala of the nose from the tip of the nose to the base of the ala on the normal side. This length can then be related to the affected side to compare the apparent defect with the true defect.

When cheek tissue is lost, distortion of the face is due to scar contraction of the cheek which results in retraction of the lower eyelid the angle of the mouth and the lower portion of the nose (Fig 360*A*) The outline of the scar tissue on the cheek represents the apparent defect. The true defect can be outlined on the normal side the difference between the apparent and true defects can then be appreciated (Fig 360*C*)

A method for evaluating the true defect is indicated in Figure 360*C* Locations on the face are employed to establish the distance between points of measurement. For example, the distance between the angle of the mouth and the tragus on the deformed side is measured and this measurement is compared to that of the distance between the same structures on the unaffected side which is usually considerably longer The difference between these two lengths, thus represents the difference in one dimension between the true and apparent defect.

The true defect may be plotted on the unaffected side of the face. Various measurements established by this procedure include those between the upper margin of the apparent defect and the lower rim of the orbit, the posterior margin and the tragus, the lower posterior margin of the defect and the angle of the jaw the antero-inferior margin and the angle of the mouth the medial portion of the margin of the defect and the ala of the nose. All of these dimensions are marked on the ho-

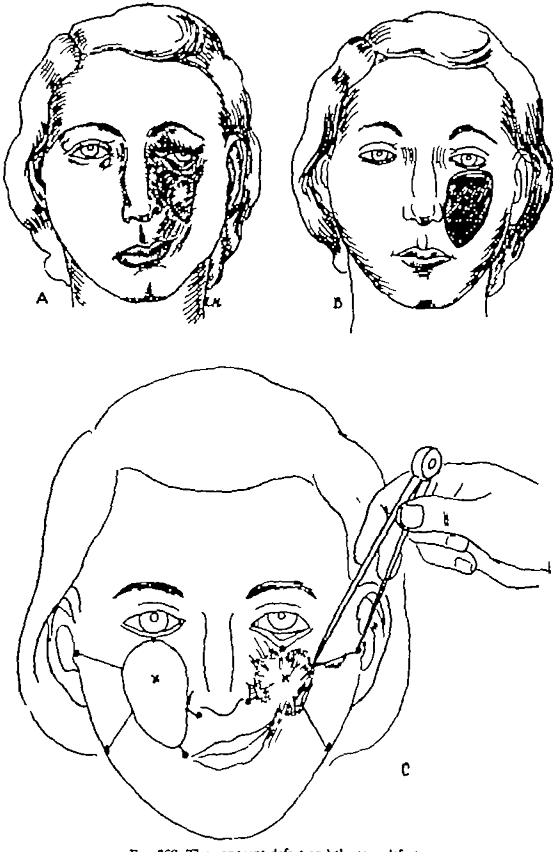

Fig 360. The apparent defect and the true defect

A. The apparent defect represented by contracted scar tissue on the left side of the face.

B The true defect becomes evident after excision of the scar tissue

C. Plotting the true defect (see text)

molateral side (Fig 360C) The points are then joined, thus outlining the defect on the normal side.

An apparent deformity in the one portion of the face may be a normal feature which has become distorted by a deformity in a different area of the face Examples of such conditions include apparent exophthalmos due to destruction or backward displacement of the orbital rim nasal deviation which on careful examination proves to be due to a deviation of the chin excessive relative protrusion of the nose due to recession of the mandible excessive relative protrusion of the chin due to underdevelopment of the middle third of the face ectropion of the eyelid due to the pull of a distant linear scar of the cheek.

The amount of flattening or loss in facial contour due to bone displacement can be determined in some cases by building up the contour with wax on a plaster cast of the face the quantity of wax used is a gross estimate of the amount of tissue required to restore the contour This method, however does not provide the exact dimensions of the proposed bone graft because evaluation of the size of the implant is determined without the measurement of the thickness of the overlying soft tissue. Cephalographic determinations have made the preoperative diagnosis in such cases a more precise method of evaluating the size and shape of the proposed bone graft.

Roentgenograms and Cephalograms

Radiological examination is an essential element in the diagnosis of bony deformities of the face

Accurate diagnosis in some cases of multiple fractures of the facial bones may be difficult. When both maxilla and mandible are fractured and displaced the degree of displacement of the bones is often difficult to appreciate. In such cases, fixed anthropometric landmarks which are visible in cephalographic roentgenograms are helpful In planning the advancement of a malunited bone to a suitable degree of projection or a contour-restoring bone graft facial casts are of some assistance. The thickness of the soft tissues must always be considered and are often difficult to evaluate accurately Cephalographic diagnosis is particularly useful in such cases and is of particular value in mandibular deformities (Converse and Shapiro 1954)

The development of cephalometric techniques owes its origin and stimulus to special apparatus designed by pioneers in the field of cephalometry (Broadbent, 1931 1937 Margolis, 1940 1947 Higley 1936) A valuable instrument has thus become a research tool in studies pertaining to the growth of the head and face and is also employed in clinical studies (Brodie 1941 McDowell 1941 Tweed, 1946 Wylie 1947 Björk, 1947 Downs, 1948 Krogman 1951)

Cephalometry enables the measurement of the head in living individuals, thus making possible the recording of cranial and facial dimensions between anatomic landmarks which are otherwise not visible or accessible in the living

Long-established metric determinations employed by anthropologists, Von Ihring (1872) Hrdlicka (1939) and Hellman (1932) among others have been adapted to cephalographic studies. The intersections of various planes and lines drawn upon tracings of cephalograms form angles which are measured and compared with accepted standards (Shapiro 1954)

The skeletal landmarks selected for use in this study are (1) the center of sella turcica (2) nasion and (3) menton (Figs. 361 362) These points of reference are readily located in the sagittal plane cephalogram of the adult.

It will be recalled that nasion is the most anterior point in the mid-sagittal plane of the skull at the junction of the frontal and nasal bones Menton in this study is understood to be the most anterosuperior point on the outer surface of the bony chin this point is also referred to as pogonion

A line drawn on the tracing of the sagittal plane cephalogram between nasion and

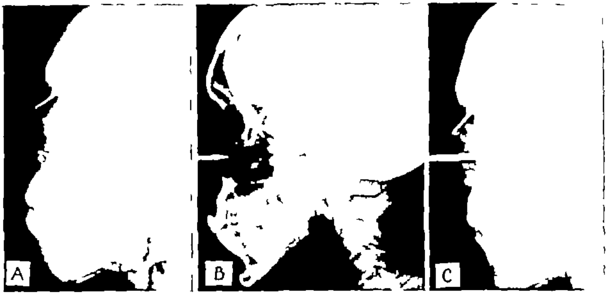

FIG 361 Sagittal plane cephalograms of an underdeveloped mandible

A. Preoperative view showing contour of hard and of soft tissue.

B. Preoperative view showing bony structure.

C. Postoperative view showing bone graft consolidated to the symphysis and improvement of the facial profile.

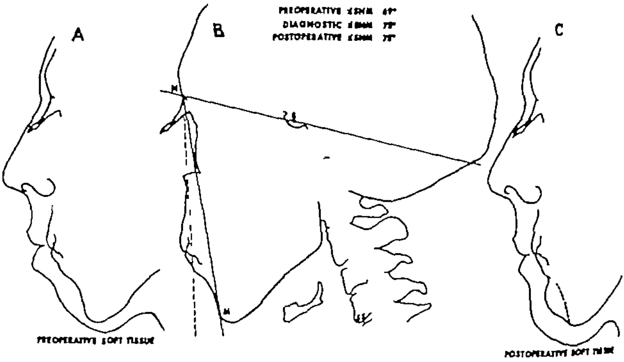

FIG 362. Tracing of the cephalograms in Figure 361

A. Preoperative soft tissue profile.

B Cephalographic diagnostic planes and angles drawn on a tracing of the cephalogram in Figure 361

C. Postoperative soft tissue profile. The degree of improvement of the profile is indicated (Figs. 361 and 362 from J M Converse and H. H Shapiro, Am. J Surg 88 858, 1954)

the center of sella turcica is the base line in this study a line drawn between nasion and menton is the facial plane

Previous cephalographic investigations by Margolis (1917) have shown that the angle formed by the intersection of the cranial base line of Margolis (spheno-occipital suture to nasion) and the facial plane averages 72 ± 3 degrees in the well balanced face As the spheno-occipital suture is closed

in the adult, the base line routinely employed in our studies is nasion to the center of sella turcica (Brodie 1941) The angle of 75 degrees is employed as a standard of comparison for angles at nasion employing the cranial base line of nasion to the center of sella turcica.

A few years ago we became interested in applying cephalometric techniques to problems associated with reconstructive plastic surgery of the face and jaws. Since that time we have employed cephalographs of facial malformations to attain symmetric results in the correction of such deformities (Converse and Shapiro 1954)

The cephalometric roentgenogram is employed in preoperative diagnosis and planning

As an example let us presume that we wish to restore the contour of the mandible by means of onlay bone grafts The thickness of bone required to restore an adequate contour may be determined preoperatively by the cephalometric technique. Cephalometric roentgenograms using both hard and soft rays are employed (Fig 361) The soft rays reveal the soft tissue contour (Fig 361*A*) the hard rays show a well-defined outline of the bony framework (Fig 361*B*) Placing the roentgenograms over a tracing box, pencil tracings are made with tracing paper of the soft tissue profile contour and bony outline (Fig 362*A* *B*) A corrected contour is traced (Fig 362*C*) The size of the required bone graft is obtained by measuring the distance at menton of the modified facial plane. The use of the posterior-anterior cephalogram also permits calculations of the required height of the bone graft. Another example of the value of the cephalogram in diagnosis and preoperative planning is shown in Fig 363 The mandible failed to develop due to forceps injury at birth and the temporo-

Fig 363

A. Photograph of patient with mandibular atresia attributed to forceps injury at birth. (See result obtained in this patient, Fig 943 Chapter 24)

B. Cephalometric roentgenogram of the facial skeleton (From J M. Converse and H H. Shapiro, in publication)

mandibular joints were ankylosed. Following surgical relief of the ankylosis, reconstruction of the mandible was planned by osteotomy of the body and bone grafting. A tracing of the body of the mandible was made on a piece of heavy cellophane paper (Fig 364*A*). The pattern was cut along the outlines of the proposed osteotomy and the

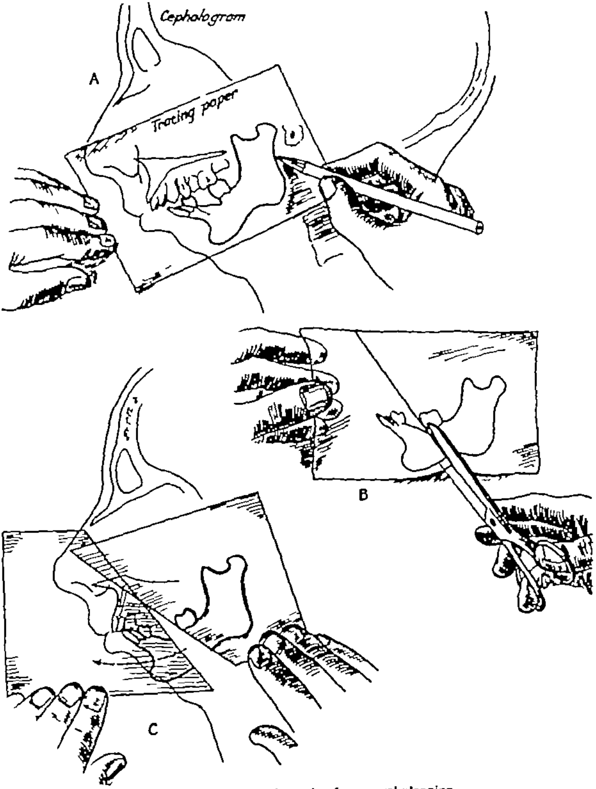

Fig 364 Cephalometric tracing for surgical planning

A. Tracing of bone outline made from the cephalogram

B. The pattern is cut at the site of the proposed elongation osteotomy

C. The anterior portion of the cut pattern is shifted and rotated forward into a position improving the dental occlusal relationships and the facial contour (*From* J M Converse and H H Shapiro In publication)

anterior portion of the body was advanced and rotated (Fig 364B) The position of this fragment and the size of the required bone graft to fill the defect in the man dibular body could then be calculated in advance (Fig 364C)

Reasons for Postponing the Operation

Temporary or even indefinite postponement of a reconstructive operation may occasionally be necessary for reasons which include infection insufficient lapse of time after healing of the primary wound, and psychological factors.

Varying periods of time, depending upon the vascularity of the region should be permitted to elapse following the healing of the original wound, before reconstruction is initiated. Latent infection disappears during this period and gradual softening of scar tissue occurs by re-establishment of the hemic and lymphatic circulation.

Choice of Surgical Procedure

The quality of the repair depends upon operative skill and judgment in selecting the operative procedure. It is sometimes preferable to leave a minor secondary defect in order to eliminate a major primary deformity Facial appearance may also be improved by a type of camouflage exemplified by the procedure employed in malunited fracture of the zygoma, in which contour is restored by a bone graft instead of attempting to replace the zygoma, a more difficult task in some cases

When transferring skin to the face a good match in color thickness and texture is important for the skin of the transplant must harmonize with the surrounding tissue. The choice of tissue borrowed from another area of the body to replace a defect of the soft tissue of the face requires careful consideration The texture and color of the skin of the face and neck differ from that of other areas. Unsuccessful matching of the skin results in a conspicuous patch. An example of such a patch is a hairless free skin graft placed in a normally bearded area of the face. Skin grafts or skin flaps appear whiter or more reddened in color than the surrounding skin Although redness persists for some time after grafting, the transplanted skin usually becomes paler with the passage of time Spotty or generalized pigmentation in skin grafts and skin flaps are disfiguring donor areas, therefore must be selected carefully

A general rule to follow in the repair of a facial defect is to shift adjacent tissue. When this procedure is not possible tissue is selected which is located as closely as possible to the defect for otherwise the transplanted skin appears foreign to the face.

The Barter Principle

When skin is borrowed from one area of the face to repair another the secondary deformity may be discernible, but the procedure is often desirable because a closer match of tissue is obtained than when a flap is transferred from a distant area. The principle of barter is employed in order to simplify reconstruction and also to avoid conspicuous disparity in the color and texture of the skin

In the elimination of a major primary deformity the barter principle is employed moving tissues from one area to another to repair the primary defect. In this process of "robbing Peter to pay Paul the price paid is at the discretion of the surgeon It seems obvious that good clinical judgment reduces the cost of the barter to a minimum

One example of the principle of barter is the use of a forehead flap for subtotal reconstruction of the nose. The forehead tissue is employed for this procedure because the best results are obtained by the use of forehead skin A major portion of the flap is replaced in its original site after detaching the pedicle, leaving a portion of the flap to form the reconstructed nose. A secondary defect remains *on the forehead.* This defect is repaired by the most suitable skin available in order to minimize the secondary deformity Skin removed from

the retroauricular and postaural area offers a good color match The additional defect behind the ear is repaired by a split thickness graft from the thigh which although darker than the surrounding skin is inconspicuous behind the ear A split thickness graft placed upon the forehead results in a poor repair

A more advantageous barter can be obtained when it is possible to repair the defect by means of local flaps, the secondary defect consisting of slight scars.

The Principle of Shifting the Defect

The principle of shifting the defect consists in the transfer of the defect from an area which is less favorable for repair than the secondary defect which remains after the tissue is shifted. The procedure is accomplished by closing the primary defect with an adjacent rotation or transposition flap the secondary defect is repaired by a free skin graft or another local flap The application of the principle of barter is exemplified *in the repair of defects requiring* a degree of thickness of the covering soft tissues a full thickness flap comprising both the skin and underlying subcutaneous *tissue can be employed in the zygomatic* area (see Fig 386, Chapter 16) When a transposed or rotated flap is raised from the preauricular area and is shifted forward to repair the zygomatic defect, skin of suitable color and texture is used in addition to all of the subcutaneous tissue removed with the flap from over the parotid masseteric fascia The secondary defect can be repaired by a full thickness retroauricular graft The vascularization of the graft is assured for it is placed over a firm base the parotid masseteric fascia The deficiency in the subcutaneous tissue is less obvious in the preauricular area a less conspicuous portion of the face than the zygomatic area Other examples of the principle of shifting the defect are the closure of a median forehead defect by two rotation flaps and the use of skin grafts to repair the secondary defects produced by the mobilization of the rotation flaps the restoration of an alar defect by shifting the remaining nasal tissue downward to form the new *alar border and reconstructing the resulting* full thickness defect of the side of the nose by flaps or the reconstruction of a median defect of the lower lip by shifting the remaining lateral portion of the lower lip to the mid line and repairing the laterally situated secondary defect by means of an Estlander flap from the upper lip.

Time Factor in Repair

The passage of time softens and whitens scars and smooths skin grafts and flaps, permitting the repaired tissues to adapt themselves to the underlying structures.

Time must elapse in multiple stage operations to permit revascularization and softening of scars before proceeding to a later stage in reconstruction The initial tendency to hypertrophic scarring diminishes with the passage of time this is repeatedly observed in deformities due to *burns. Reconstructive procedures are more* successful after the tendency to hypertrophic scarring has disappeared. The softening of transplanted flaps requires a period *of approximately four months* further modeling procedures of the reconstructed nose or ear for example must await this softening process.

Methods of Reconstruction

(1) A scar is removed by simple excision and the defect is closed by direct approximation after undermining the skin edges to release tension (2) the extent of the scarred area is reduced progressively by repeated partial excision (3) tissue may be borrowed from the area adjacent to the defect and transposed or rotated into the defect (4) in large defects, tissue is borrowed from a more distant donor area

Two methods of tissue transplantation are used *mediate and immediate* In mediate transplantation of skin the survival of the transplant is insured by a pedicle thus the term pedicled flap

In immediate transplantation of skin a portion of skin is completely detached from its vascular connections revascularization of the transplant occurring by the penetration of new endothelial buds from the site of implantation this type of free transplant is known as a graft. In addition to skin the transplantation of other tissues, such as bone cartilage and nerve may be required.

Adjuvant methods of treatment may be required in some traumatic deformities of the face. These include dermatological techniques, surgical abrasion of the skin and tattooing Special techniques of make up permit the masking of dissimilar skin colors in females. Orthodontic procedures are often required in developmental malformations of the jaws, or surgical prostheses may be required to restore missing portions of the face and jaws the co-ordinated services of the surgeon and the dental specialist are essential in such cases.

SUMMARY

Clinical examination of a patient with a facial deformity is important one should seek the answers to a number of pertinent questions during examination

1 How does the deformed face vary from the normal?

2. How extensive is the deformity?

3 Is the deformity unilateral or bilateral?

4 Is the deformity limited to soft tissue or does it involve underlying bony structures?

5 If limited to soft tissue one must evaluate the kind of tissue deformity is it due to distortion or to tissue loss?

6 Are motor nerves involved?

7 How much of the neighboring tissue can be utilized in repairing the defect? The presence of scars in the area of the defect influences the decision to utilize such tissue for repair

8 If neighboring tissues cannot be used, which of the distant tissues should be utilized?

9 The plan of treatment varies with the sex and age of the patient.

10 Finally one should be aware that all preconceived plans of treatment are subject to modification as treatment progresses.

15

THE TRANSPLANTATION OF TISSUES

To transplant or to graft, two verbs of Latin and Greek derivation respectively designate the removal of a group of living cells from a donor area and their transfer to a recipient site where they are capable of propagating a lineage of living cells. The term implantation is also employed as a synonym for transplantation.

Various terms have become accepted to define the modes of transplantation *autograft* designates a graft transferred from one area to another in the same individual *homograft* defines a graft transplanted between individuals of the same species *heterograft* indicates a transplantation of tissue between individuals of different species.

The term *isograft* is usually employed to designate a homograft between highly inbred (genetically pure) strains of animals. *Syngenesiotransplantation* is the grafting of tissue not between two individuals of ordinary genetic diversity as in the homograft, but between individuals of close genetic relationship *Brephoplasty* (May 1951) indicates the grafting of embryonic tissues.

Survival and Cell Replacement Grafts

It has become customary to divide grafts into two groups grafts in which the cellular elements survive or homovital grafts (Longmire 1952) and grafts mainly replaced by cells from the host or homostatic grafts. Examples of survival grafts are skin and cartilage examples of replacement grafts are bone nerve and arterial grafts.

The distinction between the two types of grafts does not appear to be so clear-cut in the light of recent investigations. In bone and artery grafts, it is generally accepted that the grafts serve primarily as a framework for invading host cells, although in fresh autogenous bone grafts the possible role of *surviving graft bone cells has not* yet been established. Cell survival in skin grafts, is acknowledged because of the persistence of the gross appearance of the graft following transplantation abdominal skin transplanted to the face, for example preserving the appearance of abdominal skin, or because of the survival of hair follicles in the graft. Peer (1957) has offered as additional evidence of cell survival of epithelial cells, their identification through the chromatin technique (Barr and Bertram 1949). He has obtained prolonged survival of skin homografts transplanted between mother and male infant the female chromosome persisted in the transplanted skin thus demonstrating the survival of the maternal epithelium in the graft. Other workers have observed extensive degenerative changes and replacement of the dermal elements in skin grafts. All skin grafts undergo varying degrees of cellular replacement although the extent of the degenerative process varies with the thickness of the graft thick grafts are revascularized more slowly than thin grafts degenerative processes and cellular replacement occur to a lesser degree in thin skin grafts than in thicker ones.

AUTOGRAFTS AND HOMOGRAFTS

Autografts are usually successful providing that technical details are followed. Homografts of skin are rejected after the host has made a semblance of accepting them the cause of this rejection seems to be an immunological process, known as the homograft reaction the nature of this phenomenon is discussed later in the text

For many years after Reverdin Ollier Thiersch Wolfe and Krause propagated the use of skin grafts in clinical surgery no critical distinction was made between autografts and homografts. Lexer (1911) on the basis of careful clinical observations reported that skin homografts are never successful not even when transplanted from mother to child The possible eventual success of skin homografts however remains a current issue. It is generally acknowledged that skin homografts are successful only between identical twins and in a few authenticated cases in which a close genetic relationship exists between skin donors and recipients

Homografts of bone and cornea are successful under certain conditions. These homotransplants seem to undergo a process of cellular replacement by host cells which progressively repopulate the graft. Grafts of cutaneous tissues, cartilage and bone are the most frequently employed transplants in reconstructive surgery Because the homograft reaction has been studied mainly in skin grafts, the phenomenon is considered in relation to skin transplantation in this chapter Basic considerations dealing with cartilage and bone transplantation are discussed in Chapter 19

The Vascularization of Skin Autografts and Homografts

Although the earlier literature contains descriptions of the behavior of free skin transplants in man neither the duration of survival time nor the process of vascularization of skin homografts were investigated systematically Bert (1865) was the first to note an early connection of the blood vessels of the graft and host using the term "abouchement to illustrate the mouth to-mouth apposition of the vessels. Thiersch (1874) used the term "inosculation to signify the direct connection of host and graft vessels which he observed as early as 18 hours after the application of the graft dye which he had injected into the blood vessels of the host was seen to fill the graft vessels at that time. Garré (1888) studied histologic changes in human skin grafts from five hours to two and a half years following the application of the grafts He discounted the importance of the inosculatory process, and described actual invasion of the graft by host capillary buds which began on the third or fourth day after most of the graft vessels had become obliterated. Garré's conclusions coincided with those of Huebscher (1888) who suggested that graft survival prior to invasion by host vessels depended on plasmatic circulation *i.e* the imbibition by the graft of host plasma and cellular components. A similar opinion was expressed by Goldmann (1890) Davis and Traut (1925) demonstrated anastomosis of graft and host vessels in dogs as early as 22 hours persisting up to 72 hours after the application of the graft. These investigators stressed the subsequent host capillary ingrowth occurring by the fourth day and described it as the decisive factor in establishing the definitive vascular pattern of the graft.

The process of homograft vascularization has also been a matter of controversy Conway Joslin Rees and Stark (1952) utilizing the modified Algire tissue-chamber technique to study skin homografts in mice and Ham (1952) from injection studies of skin homografts in pigs, reported that skin homografts do not become vascularized offering this finding as an explanation of homograft rejection Taylor and Lehrfeld (1953) by means of direct stereomicroscopic technique demonstrated that skin homografts become vascularized in rats and mice.

Fig 365. Stereomicroscope employed for direct observation of skin graft vessels

Scothorne and McGregor (1953) reported histologic evidence of homograft vascularization in rabbits. Gibson and Medawar (1942) and McGregor (1955) offered histologic evidence of the vascularization of skin homografts in man. Medawar (1948) and Billingham and Boswell (1953) demonstrated the *survival of grafts in the absence of vascularization* but stressed the importance of vascularization as a preresquisite to homograft rejection

The technique for observing vessels in living skin was described by Lombard (1912) and developed by Lewis (1927). Taylor and Lehrfeld (1953) applied stereomicroscopic techniques to direct observation of the vascularization of skin homografts and autografts in rats and mice their apparatus was modified (Fig 365) for experimental studies in man (Converse and Rapaport 1956)

The arrangement of the vessels of the skin has been described by Spalteholz (1927) (see Fig 25 Chapter 1) Lewis (1927) confirmed the work of Spalteholz and designated the subpapillary venous plexus and its overlying and adjoining terminal arterioles capillaries and collecting venules as *minute vessels* (Fig 366)

Stereomicroscopic observation of skin grafts permits continuous study of the *minute vessels and of the flow of blood* through them. The term flow may be defined as the passage of hemic formed elements through the vessels. The diameter of the vessels *is directly proportional* and the rate of the flow is inversely proportional to the cell mass passing through them (Fig 367) In addition to the continuous flow observed throughout most of the graft some of the vessels exhibit a flow moving in unison with the peripheral pulse

Full thickness skin grafts in man were applied to the radial aspect of the volar surface of the forearm Examinations were made daily by the means of a dissecting stereomicroscope The grafts were evalu

ated on the basis of gross and microscopic findings In each case diagnosis of homograft rejection was confirmed by subsequent escharification and sloughing The time of appearance and duration of the subsequent changes was found to vary

Gross Observations of Autografts

Each graft had a blanched appearance at the time of application persisting for a period of approximately 24 hours (Fig 368*A*) Occasional patches of pink appeared in the graft by the second day During the first 48 hours, accompanying the initial period of healing an area of primary erythema appeared in the skin surrounding the graft the surface of the graft presented a shiny appearance with no evidence of edema.

The graft assumed a pink tint on the third or fourth day and the surrounding erythema and edema disappeared (Fig 368*B*) Surface epithelium desquamation and active regeneration and merging of graft and host epidermis occurred on the sixth or seventh day (Fig 368*C*) The surface of the graft eventually became covered with shiny new epithelium which increased in thickness and lost its shiny character

The graft became pale between the tenth and twelfth day and by the twentieth day resembled the color of the surrounding skin.

Stereomicroscopic Observations of Autografts

The surface of the graft appeared pale and homogenous on the first postoperative day and no vessels could be detected Vessels which gradually became dilated and filled with static blood were observed within the next 24 hours (Fig 369*A*) A sluggish flow of blood could be seen by the third or fourth day (Fig 369*B*) the flow increased in vigor and became generalized on the fifth or sixth day Active flow in many vessels of fine caliber appeared at this time (Fig 369*C*) The number of these vessels increased up to the seventh or eighth day and many of the dilated vessels observed during the first days were no longer evident. The change in the vascular pattern coincides with active graft epithelium desquamation and regeneration By the tenth day the total number of vessels decreased remaining vestiges of dilated vessels waned and the appearance of the vascular pattern of the graft approximated that of the surrounding skin.

Fig 366 Schematic drawing of the minute vessels as seen on stereomicroscopy of the skin (after Lewis, 1927)

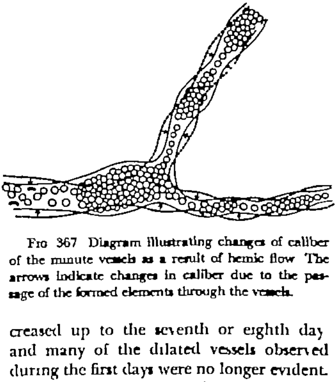

Fig 367 Diagram illustrating changes of caliber of the minute vessels as a result of hemic flow The arrows indicate changes in caliber due to the passage of the formed elements through the vessels.

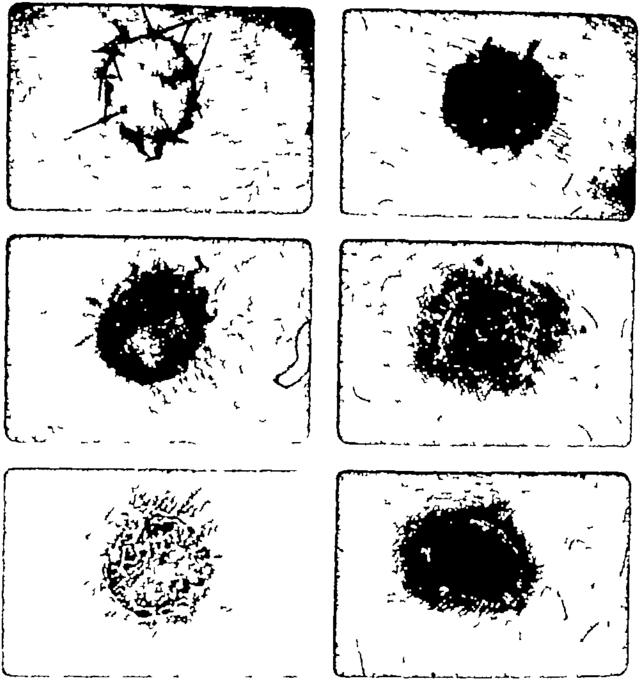

FIG 368. Gross appearance of skin autografts and homografts at various stages after transplantation (*Top left*) Appearance of graft 24 hours after transplantation Note blanched appearance (*Center left*) Autograft on the fourth day Note pink color of the graft (*Bottom left*) Autograft on the seventh day Surface epithelium is being desquamated. Note merging of graft and host epidermis. (*Top right*) Homograft on the sixth day Note the cherry-red color and the secondary erythema appearing around the graft (*Center right*) Homograft on the ninth day The graft has cyanotic appearance and the secondary erythema has increased (*Bottom right*) Homograft on the twelfth day The graft has become eschanfied

Gross Observations of Homografts

No differences were detected in the gross appearance of autografts and homografts during the first five postoperative days After the disappearance of the primary erythema a halo of secondary erythema and edema surrounded the homograft by the seventh day This change attained its maximum intensity on the eighth or ninth day The pink color of the homograft deepened after the sixth day became cherry red in color (Fig 368*D*) and appeared cyanotic

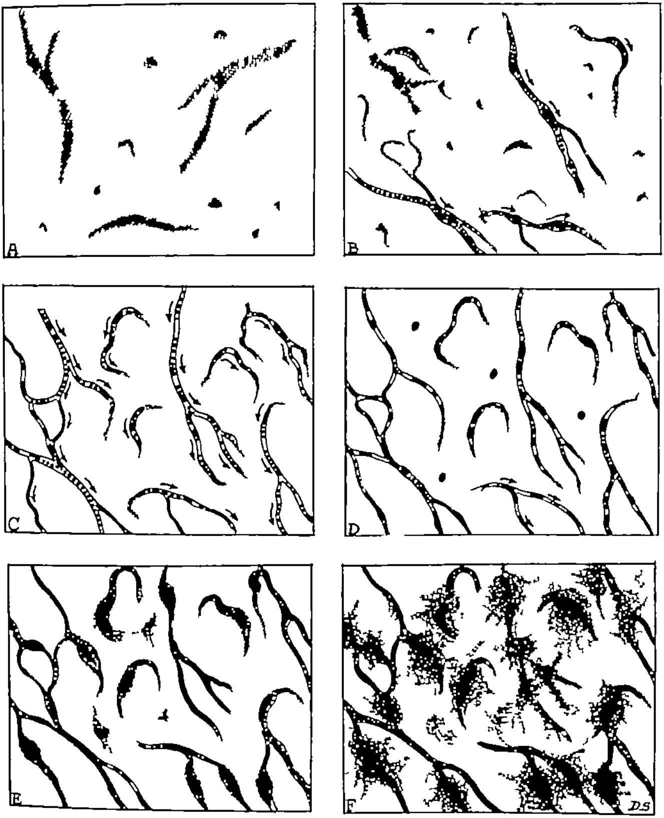

FIG 369 Drawings illustrating the stereomicroscopic appearance of the minute vessels in skin grafts.
A. At 48 hours dilated vessels can be seen.
B On the third or fourth day a sluggish flow is established
C. Active flow is observed by the fifth or sixth day
D Multiple thrombi appear in the vessels of the homografts around the eighth day Flow ceases.
E. In homografts the thrombosed vessels are dilated during the subsequent twenty hours.
F The final event in homografts is the rupture of the vessel walls with extravasation of blood rendering further stereomicroscopic examination impossible

(Figs. 365 to 369 from J M Converse and F T Rapaport, Ann Surg., 143:306, 1956)

by the ninth day (Fig 368*E*) The homograft showed only a minimum degree of desquamation and merging with the surrounding skin the autograft at this period displayed marked activity

The homograft became swollen as the color changes occurred rising above the surface of the surrounding host skin and acquiring a pneumatic appearance which increased to the ninth or tenth day

Graft dessication and escharification followed leaving a dry and opaque surface on the twelfth or thirteenth day (Fig 368*F*) The graft, a brownish eschar by the fifteenth day became sloughed by the twentieth day leaving a dermal pad in the host bed

Stereomicroscopic Observations of Homografts

The stereomicroscopic appearance of autografts and homografts was identical during the first five postoperative days On the sixth day the vessels of the autografts showed active blood flow proliferation of fine-calibrated vessels and gradual disappearance of the dilated vessels which were seen during the first few days. In the corresponding period the vessels of the homograft exhibited progressive dilatation and diminished blood flow attaining two or three times their original diameter The flow of blood lessened and ceased by the eighth or ninth day In the following twenty four hours, multiple punctate thrombi were noted along the course of the vessels (Fig 369*D*) rupture of the vessel walls with extravasation of blood followed (Fig 369*F* *F*) graft landmarks became blurred escharification ensued and the field became opaque

After sloughing and re-epithelization of the remaining dermal pad profuse vascularization and active blood flow were observed in the area.

These findings are in agreement with the work of Thiersch Carre, and Davis and Traut who have shown that host vessels do not enter the graft until the third or fourth postoperative day Hynes (1951) has reported that skin grafts contain no blood cells at the time of transplantation In our experimental series, all grafts were pale and ischemic at the time of application These observations suggest that the early filling of the vessels occurs by a process of inosculation of host and graft vasculature Vessels, progressively filled with static blood, were observed within the following twenty four to thirty-six hours. It is also suggested that ingrowing host vessels are responsible for the definitive circulation in skin grafts. Graft survival prior to the establishment of this definitive vasculature may be the result of the combined effects of direct diffusion of nutrients into the graft and early inosculation

Factors which interfere with graft-host surface apposition seem to hamper the development of early vascular connections. Inosculation of graft and host vessels, with subsequent early development of observable blood flow as well as ingrowth of host vessels, are favored when all bleeding has been arrested in the graft bed and when subcutaneous fat has been adequately removed from the dermal surface of the graft Unfavorable conditions may account for the delayed apearance of flow in some of the autografts, and the absence of flow in several of the homografts. Indeed the rejection phenomenon may have been initiated in some homografts at a time when only the deeper vascular stratum of the grafts had established contact with host vessels. The minute vessels may therefore not have had the opportunity to exhibit flow Scothorne and McGregor (1953) offer a similar explanation for the lack of success in injecting the vessels of homografts in pigs, at a time when rejection changes had probably begun (Ham 1952)

The Vascularization of Skin Homografts

Our observations are in agreement with previous work by Gibson and Medawar (1942) Scothorne and McGregor (1953) and

Taylor and Lehrfeld (1953) and indicate that human skin homografts become vascularized. The gross and stereomicroscopic appearance of autografts and homografts are identical in the early stages. The similarity persists until the rejection of the homografts is observed. Scothorne and Tough (1952) have reported evidence of this close early resemblance between autografts and homografts on the basis of histochemical determinations.

The Homograft Rejection Period

The homograft rejection phenomenon is an orderly progression of events including the development of secondary erythema around the affected homograft, homograft edema, cyanosis, thrombosis of graft capillaries, and eventual necrosis and sloughing. A dermal pad which acts as a vector for ingrowing host epidermis remains in the bed.

The sequence of events leading to the rejection of the homografts, is heralded by the cessation of flow in the graft vessels. The progressive arrest of flow extends over a period of at least twenty-four hours.

The changes observed in man are similar to those described in other species studied. The data reported by Billingham, Brent, Medawar and Sparrow (1954) for the survival time of skin homografts in chicks, mice, rats, guinea pigs, rabbits and cattle are confined to the seven- to ten-day range. The time of onset of homograft rejection in man, particularly in terms of cessation of blood flow in the graft vessels, is in close agreement with the survival time in lower forms.

Plasmatic Circulation in Skin Grafts

Huebscher (1888) and Goldmann (1890) impressed by the rapid infiltration of host mononuclear leukocytes into the vessels and dermis of skin grafts, theorized that these grafts were nourished by fluids from the host prior to the establishment of new vascular and lymphatic channels in the grafts. They termed this process of fluid nourishment the "plasmatic circulation" of a graft. Thiersch (1874), studying the histology of experimental full thickness skin grafts in man, described "inosculation" or the direct connection between graft and host vessels as early as eighteen hours after grafting. Garré (1888), observing the behavior of experimental Thiersch grafts in humans, reported endothelial mitoses in the bed of the host five and one half hours after grafting, inflammatory cells in the grafts nine hours after transplantation, and active invasion of wandering cells into the vessels of the graft seventeen hours after grafting.

Surgeons who have observed the behavior of skin grafts in their patients within the first few hours after transplantation have been impressed by the characteristic color changes in the graft which usually becomes white and blanched upon removal from the donor site. Within a few hours after transplantation it takes on a pinkish hue, which progresses to a bright pink color during the first few days following the operation. Douglas (1944) noted a faint pink tint in the graft as early as eight hours after transplantation. McLaughlin (1954), studying the color changes in a composite graft of cartilage and skin which had been transferred from the ear to reconstruct the border of a nostril, described a change from blanched white to a more harmonious cutaneous coloration within six hours after transplantation; his published report includes excellent color plates that demonstrate these changes. Hynes (1954), studying skin grafts in humans, observed that a graft contracts upon itself after removal from the donor site and expels most of the formed hemic elements from its vessels. Within twenty four hours after transplantation the graft vessels are again dilated, although they contain only a few hemic elements. Within forty-eight hours, however, the vessels contain large numbers of red blood cells.

Preliminary observations on a series of

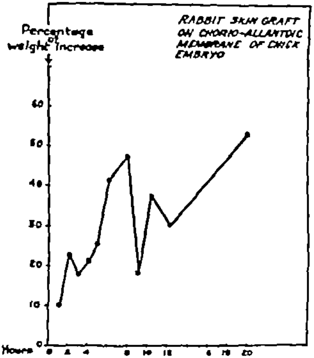

Fig 370 Curve illustrating the weight increase of skin grafts from one to twenty hours after application to the chorioallantois of the chick embryo

skin grafts placed upon the chorio-allantois of the chick embryo have revealed a rapid fluid uptake by the graft (Converse Ballantyne Rogers and Raisbeck 1957) Skin grafts taken from rabbits and transplanted to the chorio-allantoic membrane of the chick embryo were removed from the chorio-allantoic membrane host bed at intervals varying from one to twenty hours after implantation These grafts, weighed prior to implantation were weighed again following their removal by traction from the chorio-allantois. A progressive weight increase was observed in 165 grafts, as charted in Fig 370 Irregularities in the curve may be attributed to mechanical factors such as fluid loss during the removal of the graft from the chorio-allantois or undue compression of the graft prior to weighing The average increase in graft weight which was 10 per cent after one hour progressed steadily to 38.2 per cent after ten hours, and 52 per cent after twenty hours It seems conceivable therefore that skin grafts are capable of absorbing fluid from the host bed because of the sponge like structure of their dermis, which is canalized by innumerable endothelial spaces and lumena Fluid from the host bed may be absorbed in a manner comparable to that of blotting paper The rapid absorption of plasma like fluid may account for the color change in the graft.

The early filling of the graft s endothelial spaces with plasma like fluid is accompanied by the infiltration of only a few erythrocytes After twenty four hours, however the graft contains large numbers of erythrocytes, probably as the result of anastomosis of graft vessels with host vessels, coupled with the early ingrowth of host endothelium *Penetration of the graft by red blood cells may be responsible for the development of the pink color in the graft.* It can be assumed that erythrocytes enter the graft in sufficient numbers within the first few hours following transplantation to achieve this color change although their relative number is still small This assumption may account for the pinkish tint which appears in human skin grafts within the first twelve hours after transplantation. The color change progresses to a cherry-red in vascularized grafts with well-established blood flow *The cyanotic color of more slowly revascularized grafts* which appears prior to eventual progression to the cherry red hue may be due to the incomplete or inadequate hemic flow which is accompanied by an embarrassment of the venous return or drainage from the graft

"Plasmatic circulation" therefore may be described as a period during which the graft vessels fill with fluid and cells from the host bed The term circulation is actually a misnomer because the fluid absorbed by the graft from the host bed is *trapped within the graft Ingrowth of endothelial buds* from the host and direct connection of graft vessels and host vessels are concomitant processes that are probably initiated very early at the host graft junction *Endothelial ingrowth from the host*

progresses until a definitive vasculature is established. The stagnant fluid absorbed by the graft during the early phase of plasmatic circulation is apparently drained off by the establishment of a definitive blood and lymphatic circulation. Clinically, skin grafts in man usually appear edematous and their surfaces are elevated above the surrounding host skin during the early postoperative course. Within a few days following transplantation, however, the graft flattens and edema subsides. This phenomenon can presumably be accounted for by the establishment of hemic flow and by evacuation of the fluid initially trapped in the graft. When hemic and lymphatic connections between homograft and host are initiated (after 48 hours), the antigenic stimulus for the homograft reaction occurs (Converse, Ballantyne and Woisky, 1957).

Transplantation Immunity and the Homograft Reaction

The apparent acceptance by a host of a skin graft which has been transplanted from another individual of the same species is followed by the early rejection of the transplant. The process of rejection is termed the *homograft reaction*, a manifestation of transplantation immunity. The homograft rejection reaction is a highly specific phenomenon induced against the incursion of a tissue which is foreign to the host. The homograft reaction is the sole test of transplantation immunity because of the absence to date of techniques *in vitro* for the demonstration of antibodies against a homograft.

Medawar (1958) attributes to Jensen (1903) the inception of the idea that the homograft rejection is mediated by a process of active immunity. Jensen used this term to describe the process by which a transplanted tumor in the mouse is first harbored and then rejected by the animal. The homograft rejection reaction is a readily observable response which shows many of the gross aspects of an immunological process; an impressive array of experimental data tends to support the immunological hypothesis.

The Second-Set Phenomenon

The properties of the homograft rejection reaction show close similarities to the events observed in the secondary responses of orthodox immunological systems. After rejection of a homograft from one donor, the animal is in a specifically sensitized condition against further challenges from that donor. If a second homograft from the same donor is then applied, it is destroyed in an accelerated fashion (the *second set phenomenon*, Medawar, 1944, 1945). Whereas the first-set homograft is rejected within seven to ten days after application, second-set grafts seldom survive beyond the fourth or fifth postoperative day. Additional repeat-set homografts in man show no further lessening in the recipient's rejection time but are destroyed at the same rate as the second-set grafts (Rapaport and Converse, 1958).

The Recall Flare and the White Graft Reactions

At the time of rejection of a repeat-set skin homograft in man, a reaction of erythema and edema, described as the *recall flare* (Rapaport and Converse, 1957), occurs at the site of the immediately preceding homograft rejection site (Fig. 371*A*, *B*). This phenomenon has many well-described analogues in the annals of delayed hypersensitivity. Its occurrence, for example, has been described at the site of previously negative tests in patients who had become tuberculin positive by leucocyte transfer of tuberculin hypersensitivity (Lawrence, 1949). It has also been noted in man that in every repeat-set homograft applied within one week after rejection of the preceding homograft from the same donor, the homograft failed to show the color changes characteristic of vascularization. The graft remained white (Fig. 371C); this particular type of reaction has been termed the *white graft reaction*

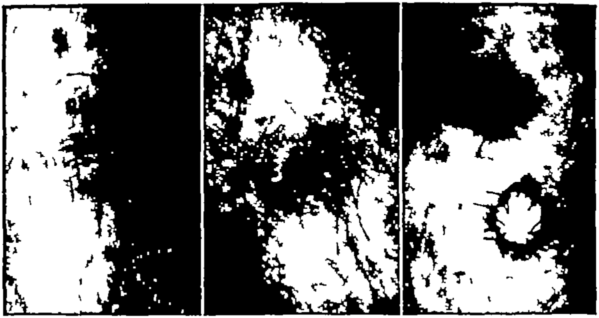

Fig. 171 Repeat-set skin homografts

(*Left*) Quiescent site of previously rejected skin homograft (repeat-set homograft No. 3)

(*Center*) Recall flare and hemorrhagic necrosis of previously quiescent skin homograft site (repeat-set homograft No. 3) at the time of rejection of repeat-set homograft No. 4

(*Right*) (*Bottom*) White graft reaction in homograft five days after transplantation (*Top*) Normal appearing homograft five days after transplantation

(F. T. Rapaport and J. M. Converse Ann. Surg 147:273 1938)

(Rapaport and Converse 1958) The white graft reaction has been confirmed in the rabbit by Stetson and Demopoulos (1958) It is interpreted as signifying a hyperimmune state preventing the ingrowth of host endothelium

The Transfer of Hypersensitivity to Homotransplants

Mitchison (1955) has shown that specific sensitivity to tumor homografts is transferred in mice by means of lymph node cells obtained from sensitized animals. Billingham Brent and Medawar (1955) demonstrated a similar transfer of sensitivity to skin homografts in mice Voisin and Maurer (1957) reported similar results in guinea pigs This phenomenon has many analogies in the field of delayed hypersensitivity It has been shown repeatedly since the pioneering work of Landsteiner and Chase (1942) that hypersensitivity of the delayed type can be transferred by means of viable leukocytes obtained from sensitized animals. That this phenomenon can also be extended to man was shown by Lawrence (1919)

The Phenomenon of Adaptively Acquired Tolerance

Billingham Brent and Medawar (1953 1955) defined acquired immunological tolerance as an induced state of specific non reactivity toward a substance that is normally antigenic a non reactivity moreover that is due to a primary failure of the mechanism of the immunological response"

Administration of an antigen prior to the development of the recipient's immunological response mechanisms instead of sensitizing lowers the capacity of the animal to react to the antigen when it has matured. Exposure of the embryo by injection *in utero* or of the new born to a given antigen prior to the development of its immune mechanisms causes it to react to subsequent exposure to the antigen as if the antigen were part of its own make-up *i.e.* as though it were not an antigen at all

but part of itself This phenomenon differs from another immune phenomenon immunoparalysis (Felton 1949) which depends upon flooding the adult body with antigen

A similar state is found in dizygotic twins in cattle cross-tolerance to skin homografts exists due to the intermixture of their blood streams *in utero* (Owen 1945) Hašek (1953 1954) was successful in reproducing this phenomenon by joining the chorio-allantoic membranes of two fertilized eggs, resulting in vascular anastomosis between the two embryos. After hatching, successful cross-homografting between the two chicks was possible for as long as two years after birth (Ha ek, 1957)

The work of Billingham, Brent and Medawar (1953 1955) as well as that of Woodruff (1957) has established the reproducibility of the phenomenon of adaptively acquired tolerance Both groups of investigators were able to induce tolerance to skin homografts in the rat when spleen cell suspensions were injected shortly after birth

The analogies of the system of adaptively acquired tolerance to other described immunological phenomena are of great interest, and support the suggestion that tissue homotransplantation reactions are a part of the immune responses of the individual.

Antigens and Antibodies in Tissue Homotransplantation

For many years the opinion prevailed that the determinant of homograft reactivity was the living nucleated cell Whole blood may elicit the homograft reaction but this function is limited to the leukocyte fraction and is not the property of either the erythrocytes or platelets (Medawar 1946) Recent studies have shown that homograft reactivity is "type" specific rather than tissue specific, and that there is no serious distinction between the various tissues of the body an animal sensitized to a donor s skin for example will respond with a second-set accelerated type of rejection if subsequently challenged with the kidney of the same donor

Research first suggested that the antigens are either desoxyribonucleoproteins, or are closely associated components of chromosomal protein Billingham Brent and Medawar (1956) were able to demonstrate antigenic activity in totally desintegrated splenic cells and in solutions made from them. By dispersing and degrading desoxyribonucleoproteins in aqueous solution with ultrasonic vibration and then precipitating with 0 15 M-sodium chloride it is possible to disengage the antigens from almost the whole of the DNA-containing matter (Medawar, 1958) These authors are working on the hypothesis that the determinant groups of the antigens responsible for the homograft reaction are amino-acid polysaccharide complexes.

Just as there have been significant advances in the study of the antigen groupings responsible for the elicitation of homotransplantation immunity there have also been re-examinations of the participation of circulating, or serum antibodies in homograft rejection Gorer (1955) demonstrated the presence of circulating cytotoxic iso-antibodies in a patient who had received skin homografts Stetson and Demopoulos (1958) elicited circulating antibodies in rabbits which could passively and selectively effect the white graft reaction Bollag (1956) reported the appearance of serum antibodies following skin homografting as revealed by nephelometry Another significant fact has been the persistence of skin homografts in agammaglobulinemic human patients (Good and Varco 1955) in whom serum antibodies were absent.

Histopathologic Studies

The response to the challenge presented by a growing skin homograft in a recipient animal is found in the draining regional lymph node (Mitchison 1955) which exhibits characteristic changes including the appearance of what Mitchison described as

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(*Right*) (*Bottom*) White graft reaction in homograft five days after transplantation. (*Top*) Normal appearing homograft five days after transplantation

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Antigens and Antibodies in Tissue Homotransplantation

For many years the opinion prevailed that the determinant of homograft reactivity was the living nucleated cell Whole blood may elicit the homograft reaction but this function is limited to the leukocyte fraction and is not the property of either the erythrocytes or platelets (Medawar 1946) Recent studies have shown that homograft reactivity is "type" specific rather than tissue specific, and that there is no serious distinction between the various tissues of the body an animal sensitized to a donor s skin for example, will respond with a second-set accelerated type of rejection if subsequently challenged with the kidney of the same donor

Research first suggested that the antigens are either desoxyribonucleoproteins, or are closely associated components of chromosomal protein Billingham Brent and Medawar (1956) were able to demonstrate antigenic activity in totally desintegrated splenic cells and in solutions made from them. By dispersing and degrading desoxyribonucleoproteins in aqueous solution with ultrasonic vibration and then precipitating with 0 15 M-sodium chloride it is possible to disengage the antigens from almost the whole of the DNA-containing matter (Medawar 1958) These authors are working on the hypothesis that the determinant groups of the antigens responsible for the homograft reaction are amino-acid polysaccharide complexes

Just as there have been significant advances in the study of the antigen groupings responsible for the elicitation of homotransplantation immunity there have also been re-examinations of the participation of circulating or serum antibodies in homograft rejection. Gorer (1955) demonstrated the presence of circulating cytotoxic iso-antibodies in a patient who had received skin homografts Stetson and Demopoulos (1958) elicited circulating antibodies in rabbits which could passively and selectively effect the white graft reaction Bollag (1956) reported the appearance of serum antibodies following skin homografting as revealed by nephelometry Another significant fact has been the persistence of skin homografts in agammaglobulinemic human patients (Good and Varco 1955) in whom serum antibodies were absent.

Histopathologic Studies

The response to the challenge presented by a growing skin homograft in a recipient animal is found in the draining regional lymph node (Mitchison 1955) which exhibits characteristic changes including the appearance of what Mitchison described as

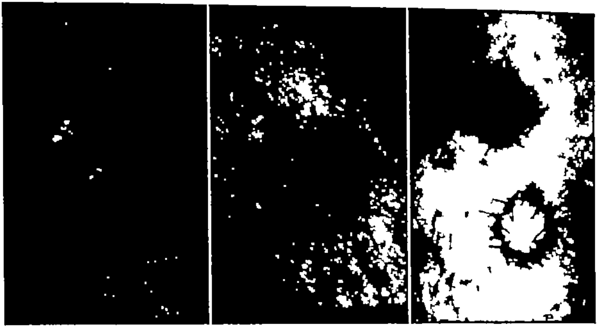

FIG. 371 Repeat-set skin homografts.

(*Left*) Quiescent site of previously rejected skin homograft (repeat-set homograft No. 3)

(*Center*) Recall flare and hemorrhagic necrosis of previously quiescent skin homograft site (repeat-set homograft No. 3) at the time of rejection of repeat-set homograft No. 4

(*Right*) (*Bottom*) White graft reaction in homograft five days after transplantation. (*Top*) Normal appearing homograft five days after transplantation.

(F. T. Rapaport and J. M. Converse, Ann. Surg., 147:273, 1958)

(Rapaport and Converse 1958) The white graft reaction has been confirmed in the rabbit by Stetson and Demopoulos (1958). It is interpreted as signifying a hyperimmune state preventing the ingrowth of host endothelium.

The Transfer of Hypersensitivity to Homotransplants

Mitchison (1955) has shown that specific sensitivity to tumor homografts is transferred in mice by means of lymph node cells obtained from sensitized animals. Billingham, Brent and Medawar (1955) demonstrated a similar transfer of sensitivity to skin homografts in mice. Voisin and Maurer (1957) reported similar results in guinea pigs. This phenomenon has many analogies in the field of delayed hypersensitivity. It has been shown repeatedly since the pioneering work of Landsteiner and Chase (1942) that hypersensitivity of the delayed type can be transferred by means of viable leukocytes obtained from sensitized animals. That this phenomenon can also be extended to man was shown by Lawrence (1949).

The Phenomenon of Adaptively Acquired Tolerance

Billingham, Brent and Medawar (1953, 1955) defined acquired immunological tolerance as an "induced state of specific nonreactivity toward a substance that is normally antigenic"—a nonreactivity, moreover, that is due to a primary failure of the mechanism of the immunological response.

Administration of an antigen prior to the development of the recipient's immunological response mechanisms, instead of sensitizing, lowers the capacity of the animal to react to the antigen when it has matured. Exposure of the embryo by injection *in utero* or of the newborn to a given antigen prior to the development of its immune mechanisms causes it to react to subsequent exposure to the antigen as if the antigen were part of its own make-up, or as though it were not an antigen at all.

to reinforce the suggestion of Loeb (1945) that syngenesiotransplants (transplantation between family related individuals) should provide longer survival periods it seems conceivable that a gradation in survival time may correspond to a genetic gradation.

Another point of interest is that blood from the parent donor was transfused to the homograft recipient in two of the successfully homografted patients previously cited. Snell (1952) suggested a possible influence of these blood transfusions in determining the successful outcome of the homografting, and described under the term *enhancement* the prolonged or permanent survival of transplanted tumors produced by prior injections of lyophilized tissue Prior blood transfusions from the donor of the skin homografts could have an enhancing effect on the survival of skin transplanted to the recipient.

In hypothesizing upon the effect of blood group antigens on the ultimate outcome of skin homografting, it may be possible that a gross genetic similarity of skin antigens between donor and recipient is reinforced by a gross genetic similarity of blood group antigens. Woodruff and Allan (1953) Simonsen (1953) and Pfeffer and Rogers (1955) suggest that gross compatibility of major and minor blood groups and subgroups be sought in the donor and recipient in order to increase the chances of prolonged survival of skin homografts.

Conclusions

Early workers in the field of tissue homotransplantation attributed the rejection of homografts to differences in chemical structure between graft and host termed by Loeb (1945) "individuality differentials" There is no serious inconsistency between this view and the immunological hypothesis of transplant rejection Rather the immunological hypothesis suggests one possible fashion in which the host responds to these individuality differentials. Conversely there is evidence that the transplanted tissue or cells might be capable of reacting against the host (Simonsen 1958) It has been shown that the inoculation of adult spleen cells (*i.e* immunologically competent cells) into embryos or new born mice for the induction of acquired tolerance results in premature death or stunted growth associated with widespread involution of lymphoid tissue a condition designated as runt disease (Billingham, 1957)

Despite many years of intensive research on the subject, the significance of the failure of tissue homotransplants to develop successfully in their animal hosts has remained unclear The recent past has witnessed the evolution of our ideas from Loeb's postulate of the inevitability of biologic individuality to Medawar's demonstration that tissue homotransplants were rejected as a result of the development in the host of specific hypersensitivity to these foreign materials Inevitably this was followed by attempts to identify this newly found form of "hypersensitivity in terms of other already known man-made manifestations. The classic studies of Medawar Billingham, and their associates, appeared to bear particular similarity to events noted in delayed or bacterial type hypersensitivity The subsequent brilliant demonstration by Mitchison of the transfer of homograft sensitivity by means of leucocytes obtained from sensitized donors but not by serum further supported this parallelism.

As research in tissue homotransplantation continued evidence began to accumulate, suggesting that the postulated inclusion of the homograft reaction into the realm of reactions of delayed hypersensitivity was not as much of a fait accompli" as was generally believed. Of particular importance at this point was Stetson's finding that sera obtained from adequately hypersensitized animals were capable of transferring tissue homotransplantation sensitivity and the studies of Good and Varco in agammaglobulinemics. It will be recalled that the agammaglobulinemics tolerate skin homo-

the "activated lymphoid cell" systemic, generalized hypersensitivity follows this response. That the pattern is essentially similar to that found in hypersensitization of experimental animals to more conventional antigens such as dysentery bacilli is of interest (Harris and Harris, 1957).

The experiments of Algire (1957) and of Woodruff (1957) have further shown that the homograft rejection reaction cannot occur if the graft is maintained within a diffusion chamber which is impermeable to cellular elements of the host.

Histologic, as well as studies in diffusion chambers, suggest the close analogies of some of the manifestations of homograft rejection to the patterns observed in hypersensitivity of the delayed type.

The Genetics of Homotransplantation

The work of Little (1921) suggested that the homograft reaction was an outward expression of genetic diversity. Indeed, it is the most complete single expression of genetic diversity, and no one character so thoroughly determines the dissimilarities between two individuals as the rejection of a homograft. The homograft reaction has actually been employed to demonstrate that two children, separated at birth by error and living in separate families, were identical twins (McIndoe and Franceschetti, 1950).

In addition to the evidence shown above favoring the "type" or "individual" rather than "tissue" or "organ" specificity of the antigens involved in homograft rejection, additional knowledge has been acquired in relation to the genetics of homotransplantation in studies of tumor transplants. These studies have resulted in the formulation of principles often referred to as Snell's Laws (1953). These laws resemble the general principles of blood group compatibility, and are based on the premise that homotransplants can be transferred successfully to a host having all the iso-antigens present in the transplant. Absence of a donor iso-antigen in the host brings about an immune response which results in the destruction of the grafted cells (Eichwald, Silmser and Wheeler, 1957). It has been assumed that these laws apply equally to the transplantation of tissues that are tumor negative. Eichwald and his collaborators noted instances of graft failure that should not have occured if Snell's laws had applied fully. They demonstrated the presence of a heretofore unsuspected histocompatibility gene on the chromosome of male mice which expresses itself when the recipient is a female F1 hybrid and results in the rejection of the graft.

Bauer in 1927 successfully transplanted skin between monozygotic or identical twins in the course of an operation for syndactilism, and postulated that "homografting could be successful only if donor and host were genetically similar" (Rogers, 1957). Other surgeons (Padgett, 1932; Brown, 1937; Schattner, 1914; Converse and Duchet, 1917; McIndoe and Franceschetti, 1950; Blandford and Garcia, 1953) have confirmed the success of homografting between identical twins.

Rogers (1957) demonstrated that skin homografts transplanted between dizygotic or non identical twins survived longer (nineteen to twenty-nine days) than homografts cross-transplanted between individuals of ordinary genetic diversity (seven to nine days).

Examples of the long survival of skin homografts in critically burned patients may be accounted for on the basis of increased cortico-steroid activity and also because most donors of skin homografts are usually immediate relatives of the patient. In four cases (Wolf, 1916; Kearns and Reid, 1919; Caby, 1952 and Meek, 1951) skin homografts appeared to survive permanently. The donors in these cases were the patient's parents. It is significant that there has been no authenticated case of permanent survival of skin homografts between non-related individuals. These facts appear

gauze the whole was enclosed in two sterile towels and stored at 4 C. Webster reported that, in a number of cases such tissues had survived a storage period of three weeks when implanted as autografts in suitable recipient areas.

Survival of human skin for longer periods was reported by Matthews (1945) He placed the tissue in a tube surrounded by gauze which had been wrung out in saline solution, and kept the wrapped tissues in a stoppered bottle in an ice box. Flatt (1948) employing a similar procedure obtained satisfactory results following a storage period of two months.

Other investigators strove to determine the optimum conditions of survival of skin when stored in a similar temperature range. Hanks and Wallace (1949) experimenting with rabbit skin, found 10 per cent serum superior to oil as a storage medium. They based their assessment of the viability of stored tissue upon culture *in vitro* of tissue samples, and attributed the superior survival of the serum-stored tissues to nutrients provided by this medium and also to the buffering action against acids liberated by tissue metabolism Marrangoni (1950) and Allgöwer and Blocker (1952) confirmed the superiority of dilute serum as a medium for the storage of rabbit and human skin grafts at ice box temperature.

These experiments indicate that the best conditions for the storage of skin grafts in temperatures above freezing include (1) immersion in a medium consisting of 10 per cent to 30 per cent serum in a balanced salt solution (2) the presence of air and (3) storage at a temperature of about 5 C. The viability of excised skin under these conditions, may be sustained for at least a week and, at most, for a period of two months. The viability of the stored tissue progressively declines during this storage period, however and *prolonged storage* introduces the risk of less than complete survival.

The limitations imposed by the relatively brief storage time at above 0 C. temperature has induced additional investigation in storage and at temperatures below freezing

Storage at Temperatures below Freezing

It has been hypothesized that if the metabolic activity of an isolated tissue or organ could be completely or almost completely suppressed the tissue might be preserved indefinitely in a dormant but potentially viable state. This possibility has been given consideration by biologists who have observed the revival of plant seeds and some lower organisms when rewarmed after long periods at subfreezing temperatures.

Most tissues of higher animals, however have failed to resume vital activities after exposure to extremely low temperatures. Paul Bert in 1863 observed that autografted tissue in the rat failed to survive when submitted to temperatures below freezing Because most mammalian tissues have not survived simple freezing, investigators sought the nature of the damage caused by cold and explored methods of freezing and thawing which might permit survival

Injury due to cold is not completely understood. Killing by freezing has been related to the formation of ice crystals in the tissue and particularly within the cells (Chambers and Hale 1932 Smith, Polge and Smiles, 1951) Injury has been attributed to mechanical rupture and displacement of cytological structures by growing ice crystals and the forces of expansion and contraction accompanying temperature changes Lovelock (1953) and Smith (1954) attributed most or all of the injury to the concentration of salt in the cytoplasm due to the withdrawal of water by the formation of ice crystals

Grafts such as bone or artery homografts, whose primary or sole function is to serve as a *guiding scaffolding and to organize* the reparative activities of host cells, may be preserved quite simply There are but two primary considerations for their storage

grafts, cannot respond with serum antibodies and are capable of developing delayed hypersensitivity

The stage appeared set at this point for a reconsideration of the overall significance of the events of tissue homotransplantation An approach to this problem was suggested by Thomas in his recent summation at the Third Tissue Homotransplantation Conference (1958) Thomas very aptly noted that had the studies of tissue homotransplant rejection preceded the data accumulated in the field of delayed bacterial hypersensitivity it was likely that the latter would have been explained in terms of tissue homotransplantation events He suggested that instead of attempting to draw such parallelisms between man made manifestations, it might be profitable to consider the sum total of these phenomena in an attempt to evaluate their significance in terms of their true function in the subjects under study One possibility noted by Thomas was that the mechanism whose man made manifestations include delayed hypersensitivity and homograft rejection phenomena might be concerned with the elimination of neoplastic cells from man s circulation and with his resistance to neoplasia.

This pattern of broad biologic thinking would appear to offer a fruitful model for continued investigation in tissue homotransplantation

PRESERVATION OF SKIN GRAFTS BY REFRIGERATION FOR RECONSTRUCTIVE SURGERY

Because there is no substitute for human skin an available and adequate source of skin grafts is of major importance in reconstructive surgery Preserved autogenous skin grafts are useful in later stage reconstructive procedures. Skin homografts, although eventually rejected by the host serve as a vital even though temporary cover especially in the treatment of burns.

Under ordinary clinical conditions, survival of skin grafts, whether autografts or homografts is dependent upon revascularization The growth of new vessels in the graft and the flow of blood through these vessels are essential for graft survival. In our experience in the treatment of burns, viable homografts of skin are retained for a longer period than the non viable freeze-dried grafts. Brown Fryer and Zaydon (1955) have made similar observations. Methods of preservation should insure the retention of conditions in the graft which permit survival

Storage at Temperatures above Freezing

Mammalian tissues, excised and kept at body or room temperature become anoxemic and necrotic after a period of 48 hours, that such changes can be retarded by oxygenation or by chilling is common knowledge. It would appear therefore that tissue metabolism (oxygen nutrients, waste clearance) must be insured and the rate of metabolism retarded by a reduction in temperature in order to keep isolated tissues alive Temperatures close to 0 C. have proved most favorable for the long survival of embryonic tissues and organs (Hetherington and Craig 1939) tissue respiration is minimal at this temperature while oxygen solubility in water is greater than at body temperature.

That the viability of mammalian skin can thus be sustained was first demonstrated by Carrel in 1912. Segments of skin from a dog were sealed off in tubes containing mineral oil and stored at temperatures between 1 and 7 C. when grafted these could be transplanted with as great a degree of success as freshly excised skin grafts. Carrel found that Ringer s solution was inferior to oil as a preservative medium he also reported that fresh human cadaver skin treated similarly healed in place as well as fresh homografts.

Other investigators have employed modifications of Carrel s method. Webster (1911) wrapped fresh skin in Pliofilm over which he placed several layers of petrolatum

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since cellular survival in the graft is not essential. One consideration is the preservation of the original architecture of the tissue the other is the avoidance of chemical changes which induce or exaggerate inflammatory or foreign body reaction in the host, or as in the case of bone, destroy the enzymatic activity or a growth promoting substance in the graft. Such changes have occurred when treatment with alcohol formalin or boiling has been used.

Freeze-drying more nearly satisfies the prerequisites of a preservative method since it maintains most of the structural details of cells and presumably leaves many of the proteins and enzymes of the tissue unchanged The process involves the rapid freezing of the tissue by immersing it in liquid nitrogen or chilled isopentane high speed freezing reduces the mechanical distortion of its microscopic structure caused by the slow growth of ice crystals in and between the cells. The tissue is then kept frozen while its water is removed from the solid state by sublimation. The dried tissue is usually sealed in a vacuum and stored at room temperature.

Histological examination of the frozen dried and rehydrated tissues has shown that cytological structure is preserved best when freezing is conducted very rapidly (Hoerr 1936) This is attributed to the fact that smaller ice crystals are formed in the tissues during rapid freezing than during slow freezing The possibility of a correlation between the rate of freezing and the viability of frozen cells has been investigated by Snell and Claudman (1913) Breedis Barnes and Furth (1937), Billingham and Medawar (1952) and Keeley Gomez and Brown (1952).

Most experimentors believe that lyophilized skin grafts do not contain vital cells. Webster (1944) reported the successful take of a frozen-dried human graft details of the method of drying or indications of the amount of water remaining in the skin at the end of lyophilization however

Billingham and Medawar (1952) made a quantitative study of the ability of rabbit skin to survive desiccation from the frozen state Particular attention was given to the calculation of the water content of the skin at the completion of the dehydration process. Survival was judged by growth of the epidermis in portions of treated skin which were regrafted onto the rabbit from which they had been removed These investigators found that skin would not survive a state of dehydration in which the final over all water content was less than about 25 per cent Pretreatment of the tissue with glycerol solution did not increase the ability to withstand drying

Although lyophilized human skin may serve an important function in emergency cases by decreasing fluid electrolyte and protein loss and by alleviating pain, infection and fibroplasia (Pate, 1951), such skin is of limited use as graft material Because the tissue is not alive it can serve only as a temporary physiological dressing or at best, a stimulant or aid to the healing process of the surrounding living tissues.

Buchanan and Lehman (1952) have reported that frozen dried split-skin grafts in the dog persist for only a short period. Autografts and homografts endured for an approximately equal length of time

Despite the fact that several studies have indicated that grafts survive better after a slow rate of freezing the opinion prevails that rapid freezing is more favorable to survival. This may be due in part to the work of Luyet and Gehenio (1940) who have shown that certain organisms and single cells which are killed by slow freezing can survive if frozen at ultra-rapid rates. These authors argue that some tissues after ultra rapid freezing, especially if partially dehydrated may be vitrified or solidified without crystal formation thus avoiding damage to the [illegible] he required rate of freezing is so [illegible] be almost impossible to attain w[illegible] of tissue large enough to be of pra[illegible] or grafting

Some of the investigations mentioned above have been confined to studies of tumor tissues, embryonic tissues, single muscle cells and spermatozoa. Early experimental evidence of the survival of mammalian skin was submitted by Mider and Morton (1939) rat skin, chilled to −50 C. or lower and then thawed, was implanted subcutaneously Survival of some of the cells was evidenced by epithelial cyst formation and the presence of mitotic figures. Briggs and Jund (1944) made successful orthotopic transplantations of frozen and thawed skin in mice The use of frozen human skin autografts was reported by Strumia and Hodge (1945) Billingham and Medawar (1952) demonstrated that rabbit skin is quite resistant to damage by freezing and thawing and even to prolonged storage at −79 C. Slow freezing and rapid thawing were found to be the least damaging in these studies.

Polge Smith and Parkes (1949) discovered that treatment with glycerol solution offered considerable protection to spermatozoa against the injury of freezing Subsequent research has shown that protective pretreatment with ethylene glycol as well as glycerol has been effective in the preservation of other tissues including skin (Smith 1952 Billingham and Medawar 1952 Keeley Gomez and Brown, 1952 and Taylor and Gerstner 1956) The action of protecting solutions has been investigated by Lovelock (1954) who considered it as a buffer against the harmful concentration of salt.

Report of Our Experimentation with Animal Skin Grafts

In order to further investigate the possibilities of preserving human tissues alive in the frozen state, an experimental investigation was done in three successive phases (Taylor Gerstner and Converse, 1956) the first was an attempt to visualize the changes occurring within a cell when frozen thawed, and/or treated with protective agents the second was an assessment, by cultures *in vitro* of the degree of tissue survival after various freezing treatments the third phase was a study of the fate of treated skin grafts after implantation in experimental animals and in man.

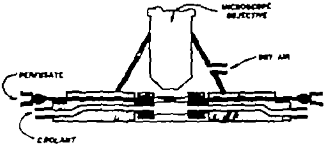

Fig 372. Drawing of special chamber for observation of changes in cells subjected to freezing and thawing

In order to determine the microscopic events occurring in cells during freezing and thawing, a special chamber was constructed (Fig 372) in which cultured cells could be chilled and rewarmed, as well as perfused and washed while being observed under high magnification and photographed in motion pictures. Observations made in the course of these studies were largely in agreement with those of A. U Smith (1952 and 1954) Cells were observed to freeze at a lower temperature than their environing medium usually by sudden crystallization after super-cooling The cells appeared quite normal immediately after thawing They were seen to disintegrate rapidly with mechanical distortion of some cells displacement of cytoplasmic structures and liberation by thawing crystals of gas bubbles in the cytoplasm No cells in which ice crystals had formed were observed to survive, but other cells, super-cooled to the same temperature without crystalizing, were undamaged The minimum effective dosage of glycerol or ethylene glycol could be determined and the effects of this pretreatment upon the freezing process was noted by direct observation of the cell response Figure 373 shows five frames taken from a motion picture of glycerol pretreated and frozen cells *A* a cell is seen before treatment *B* the cell has been perfused

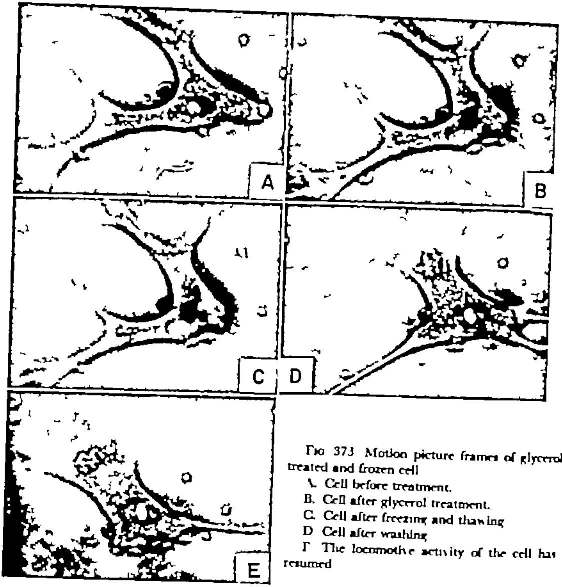

FIG 373 Motion picture frames of glycerol pretreated and frozen cell
A. Cell before treatment.
B. Cell after glycerol treatment.
C. Cell after freezing and thawing
D Cell after washing
E The locomotive activity of the cell has been resumed

with 30 per cent glycerol in Tyrode solution C the cell has been frozen to −30 C. and thawed D the cell has been washed with fresh Tyrode solution and E several minutes later the cell has resumed locomotive activity and appears normal

While the growth of a treated graft is a good test for the viability of the treated tissue it is difficult to determine with certainty whether living cells later found within the graft are treated graft cells or cells which have migrated from surrounding host tissue A large number of cultures *in vitro* of variously frozen rat and mouse skin tissues were studied by Taylor and Gerstner (1956) In these experiments no tissues showed any outgrowth when cultured after unprotected cooling to the temperature of dry ice or liquid nitrogen While these conclusions are in general agreement with experiments reported by both Smith (1952) and Pomerat and Lewis (1953) they are at variance with reports of the survival of tumor cells similarly treated (Klinke 1939) The tissue culture test was too rigorous, since tissues frozen in a similar fashion did exhibit some viability when embedded as a heterotopic graft conditions in the tissue cultures were not sufficiently favorable for the survival of cells that were severely damaged by freezing

When tissues were given protective treatment previous to freezing the effectiveness of this protection was clearly revealed in

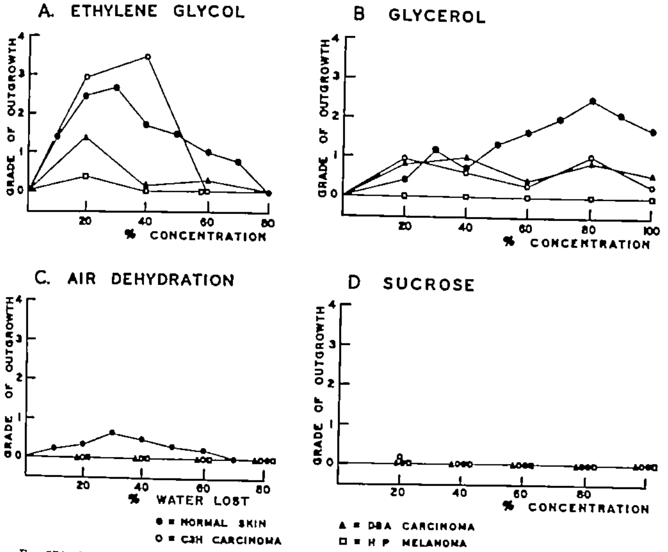

FIG. 374 Graphic illustration of tissue culture growth of tissue after various forms of protective pre treatment.

tissue culture. Figure 374 shows the results of treatment with various concentrations of glycerol and ethylene glycol

Similar tests of pretreatment with sucrose solution and simply drying of the skin be fore freezing, showed that these offered little or no protective action. The effectiveness of glycerol and ethylene glycol can therefore, not be accounted for by dehydration alone

Using the same assay *in vitro* a com parison was made of the effects upon sur vival of alteration in the rates of freezing and thawing Actual tissue temperature changes were followed by embedded ther mocouples. The freezing rates tested ranged from ultra rapid (100 /0 1 sec.) to very slow (100 /30 min) Several conclusions seem evident from these studies.

1 Unprotected tissues may be super cooled to below −20 C. without impairing survival.

2. Rapid thawing is superior to slow thawing This confirms the findings of Bill ingham and Medawar (1952) Of the several rates tested the best results were attained by warming the tissues at 100 /0.25 sec. this was achieved by immersing the frozen tissues in saline at +45 C.

3 Survival following ultra rapid freez ing was not better than survival after slower freezing

4 Little consistent difference in survival was detected between rapidly and slowly frozen tissues. A slight superiority of medium and slow over rapid cooling was indicated

5 A critical temperature range occurs between −20° C. and −35° C. The survival of skin remaining long in this range is impaired

6 Formation of ice in supercooled tissue occupies an appreciable time interval which varies with the rate of cooling Little damage is done to tissues during the major portion of this period Tissue damage occurs during the very end of this period of crystal growth.

7 Characteristics of the freezing curves of glycerol and ethylene glycol treated tissues indicate that (a) crystal formation is reduced (b) the temperature at which freezing occurs is lowered and (c) the protective agent favors vitrification in the medium and in the tissue.

An extensive series of fitted orthotopic skin grafts was compared with the tests *in vitro* The results were in agreement with the tissue culture experiments, showing a marked protective effect of pretreatment with glycerol and ethylene glycol. A sufficient number of cells survived in these protected and frozen grafts to form a grafted area with all the characteristics of normal skin.

Considerable attention was given to providing a good vascular bed for all these orthotopic grafts. Frequent stereomicroscopic observations were made to note the course of graft revascularization These observations showed that revascularization was always delayed in frozen grafts occurring as late as 5 or 7 days after transplantation In unfrozen skin grafts, blood flow was resumed in less than 3 days.

Most grafts frozen without pretreatment were invaded by cells from the host region or were undergrown and cast off Occasionally however living cells were observed adjacent to host tissue. This suggested that if the graft could be given an even more favorable environment than that offered by orthotopic placement a larger number of frozen cells might survive. This hypothesis was verified by relatively good growth

FIG 373 Histological section of unprotected frozen skin embedded in muscle showing cellular activity in sebaceous glands and hair follicles

FIG 376 Histological section of unprotected frozen skin graft 10 days after it was imbedded under the kidney capsule It shows cellular activity of the transplanted skin

from unprotected frozen skin fragments that were imbedded in muscle (Fig 375) under the kidney capsule (Fig 376) or under a flap of host skin and subsequently exteriorized (Fig 377) Histological study of these imbedded grafts showed that most of the cells of the graft never recovered. Only a few cells, favorably situated near healthy host tissue survived, and subsequently repopulated the graft to produce glands, hair and normal appearing dermis (Fig 378)

These results offer an explanation for the few cases in which frozen grafts were made in human patients. In general these followed the same pattern as that of animal grafts survival was better in glycerol protected grafts than in grafts frozen without pretreatment. In view of the thickness of the grafts used it is surprising that non protected grafts showed any surviving cells.

It is evident from this study that attention must be given not only to the type of pre treatment and method of freezing and thawing but also and of equal importance, to the thickness of the graft the nature of the bed and the type of dressing

Viable and Non viable Grafts

The term graft usually designates a transplant which is expected to survive and to become permanently adapted to the host bed grafting can be defined therefore as an act of propagating a lineage of living cells. The term graft is also employed for a transplant such as a homograft or heterograft which is not expected to survive after a limited period. These grafts show cellular proliferation for a limited period of time as a result of being revascularized by the recipient, but are rejected when immune mechanisms are developed in the host.

Frozen Dried Skin Homografts

Non viable frozen-dried skin grafts have been employed for covering raw areas resulting from deep burns where autografts are unavailable. This situation arises when

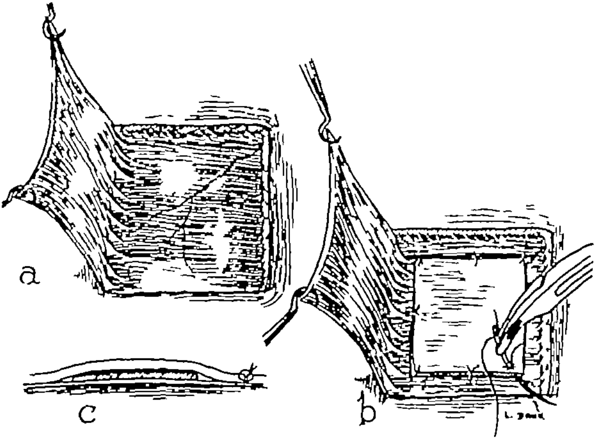

FIG 377 Drawing illustrating the technique of implanting a pretreated frozen and thawed skin autograft under a pedicled flap.

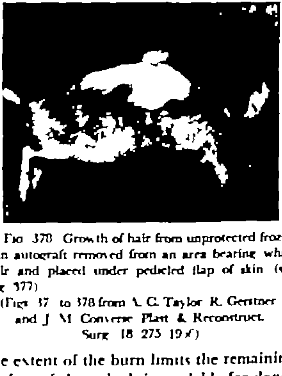

FIG 378 Growth of hair from unprotected frozen skin autograft removed from an area bearing white hair and placed under pedicled flap of skin (see Fig 377)

(Figs 377 to 378 from A. C. Taylor R. Gerstner and J M Converse Plast & Reconstruct. Surg 18 275 1956)

the extent of the burn limits the remaining surface of skin which is available for donor areas and also when the critical condition of the patient precludes an additional operative procedure for the removal of autografts Frozen-dried homografts supply a temporary covering for the burn wound, closing the wound and arresting fluid loss. Although these grafts are not viable as they do not show any evidence of growth on tissue culture (Earle 1957) they become adherent to the wound and even show color changes which assume a punctate red color reminiscent of viable skin grafts. Investigation of the fate of frozen-dried human skin grafts transplanted to the chorio-allantois of the chick embryo (Converse Ballantyne Rogers and Raisbeck 1958) shows that the connective tissue fibers of chorio-allantois interlace with the fibers of the graft thus accounting for the adherence of the graft It was noted in man that bleeding occurred when a frozen-dried graft was torn from its recipient bed three or four days after transplantation this observation would seem to suggest that the graft was

vacularized by the host. Additional suggestive evidence was obtained when vascularization was also observed on the transplants placed on the chorio-allantois which were penetrated by the membranal vessels of the chick embryo.

Frozen-dried grafts melt away progressively in a period varying between ten and fifteen days without the signs of an inflammatory immune response in the surrounding area. Frozen-dried homografts fail to remain *in situ* for prolonged periods in critically ill burned patients as is frequently observed with viable skin homografts.

16

SCARS OF THE FACE

Scars result from wounds and burns which penetrate the skin. Healing occurs without a visible scar if tissue destruction does not extend deeper than the papillary layer of the dermis (see Chapter 2) Abraded wounds resulting from accidents are frequently tattooed by foreign bodies which have become ingrained in the dermis, causing disfiguring pigmented areas such as those seen in powder burns (see Chapter 4)

Even a carefully sutured wound may show a noticeable scar in the early stages because its hard texture and pink color contrast with the surrounding tissues. As the reaction of repair subsides the scar often becomes pale soft and inconspicuous.

A number of factors intervene to produce variations in the quality of facial cicatrices these may be wide depressed contracted hypertrophic or keloidal

Wide scars result from unsutured or improperly sutured wounds, or those sutured under undue tension (Fig 379) When the wound crosses the lines of tension of the skin separation of the edges in the early stages may be followed by further widening during subsequent weeks.

Depressed scars generally occur over a soft base such as the cheek maturation and shrinkage of the collagen in the wound causes the scar to be pulled inward toward the subcutaneous fat (Fig 380). Depression of the scar occurs if the underlying tissues, particularly the layer involving the muscles of expression have not been approximated

Contracted scars are caused by longitudinal shrinking and may result in distortion where tissues are loosely attached (Fig 381)

Semicircular or U-shaped wounds surrounding a trap-door flap of skin and subcutaneous tissue leave disfiguring scars as shown in Figure 382. The horseshoe-shaped scar is depressed but the intervening flap of tissue is puckered and edematous. The puckering of the trap-door flap is due to the contraction of the surrounding scar the pull of the elastic fibers in the dermis and the tendency to curl on itself during healing Edema is due to obstruction of the lymphatic and venous flow by the peripheral scar The treatment of trap-door flaps is discussed in Chapter 4 (see Fig 87)

Irregular scars with puckering or inverted-everted edges, due to uneven or careless approximation of wound edges require secondary adjustments.

Hypertrophic or keloidal scars due to overgrowth of fibrous tissue form a special group and are considered separately

Factors Influencing the Quality of Facial Scars

The type of scar that will result from a wound cannot be predetermined salient facts, however have been noted

1 Non infected wounds leave a less visible scar than infected wounds. Infection delays healing the inflammatory changes result in an increase of fibrous tissue in the wound

2 Children and young adults result in

FIG 379 Widened scar of the cheek, the result of an automobile accident. The scar of the neck is hypertrophic.

fection and their tissues heal more readily than older individuals but they are more likely to develop wide and hypertrophic scars. Wounds in young individuals gape widely because of the pull of the rich elastic tissue of the surrounding dermis sutured wounds are submitted to tension which tends to cause a widening of the healing wound. The elderly develop fine scars because of a decrease in skin tone due to diminution in the elastic tissue content.

FIG 381 Contracted scar everting the upper lip and traversing the nasolabial fold the result of an explosion.

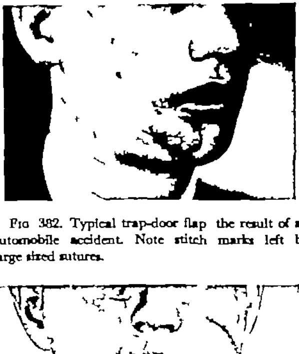

FIG 382. Typical trap-door flap the result of an automobile accident. Note stitch marks left by large sized sutures.

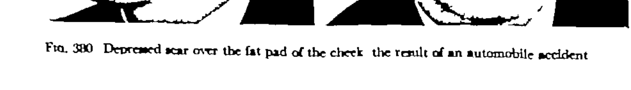

FIG. 380 Depressed scar over the fat pad of the cheek the result of an automobile accident

3 Lacerations over a firm base such as the forehead temporal region nose ears and to a lesser degree over the chin usually leave less visible scar lines than lacerations on the cheeks and side of the face where the tissues are subjected to movements produced by the muscles of facial expression. Movement and tension tend to produce thickened scars, raised above the surface particularly when they cross a skin fold

4 Scars parallel to the natural lines of expression of the face are less visible than scars which cross these lines.

The direction and location of the scar influences the quality of repair The result is discouraging to both surgeon and patient when a carefully and accurately sutured wound becomes widened or hypertrophied after healing The end result of facial scar repair depends more upon the actual location and direction of the scar than on the particular technique employed The sutured wound may leave a scar of poor quality when situated in an unfavorable position and direction In contrast when the scar is situated in or parallel to a skin fold or line of expression the healed wound is often only slightly perceptible

5 Scars may be conspicuous only because of the distortion they provoke Distortion of the nose or the lips may result from scar contraction The relief of distortion due to the pull of a scar usually achieves a dramatic improvement in the appearance of the patient

Depressed or elevated scars sometimes cast shadows which accentuate them Long straight scar lines, because of the longitudinal pull of the scar are more conspicuous than broken line scars where the pull of the tissue is counter-balanced by a pull in the opposite direction

6. The result of scar repair also depends upon the disturbance to the underlying muscle tissue caused by the initial trauma A deformity remains, despite the restoration of the surface skin if a considerable amount of muscle tissue has been destroyed for the scar prevents expressive movements.

Hypertrophic Scars and Keloids

Cicatrization occasionally remains unarrested after the wound appears to be healed connective tissue continues to form The scar appears as a faintly pink narrow line on a level with the surrounding skin surface after the primary healing has taken place The width and prominence of the scar increase between the twentieth and thirtieth day and the pink color instead of fading, becomes more conspicuous. The continued growth of vascular connective tissue elevates the scar above the level of the epithelium the scar may thus become a hypertrophic scar or a true keloid

Keloidal formation is due to excessive and abnormal fibrous overgrowth in the dermis. Keloids have been classified as spontaneous and traumatic most authors believe that spontaneous keloids are also preceded by trauma which is so slight that it is not noticed The hypertrophic scar in which connective tissue proliferation does not exceed the limits of the scar represents the smallest degree of proliferative tendency Although the term keloid does not apply to the hypertrophic scar the latter is also frequently included in the keloid group Penetration of the wound to the reticular layer of the dermis appears to be a requirement for the production of a hypertrophic scar superficial abrasion which involves the papillary dermal layer alone does not appear to produce hypertrophic scarring The slightest scratch or pin prick may result in the formation of a keloidal tumor in individuals who are predisposed to keloid formation

The tendency toward excessive fibrous proliferation was described in detail by Alibert (1835) who first used the term chéloïde a French word of Greek derivation meaning claw referring to the extensions frequently seen in keloids which invade the surrounding tissue The word is

FIG 383 Keloid showing enormous proportions attained by such tumors. In this susceptible patient, the slightest injury results in keloid formation.
(*Upper*) Photograph of keloid in male Negro.
(*Lower*) Seven years later the keloid has assumed enormous proportions.

spelled keloid in the English and German medical literature.

A hypertrophic scar on gross examination is limited to the tissue which binds the wound whereas in a true keloid, the fibrous overgrowth tends to invade the surrounding tissue with claw like processes in a tumor like fashion (Fig 383) and recurs after excision Both types of scar are characterized by an increase in the number of fibroblasts and blood vessels and by thin flat epithelium

The keloid is localized in the reticular layer of the dermis as a poorly circumscribed mass of connective tissue composed of swollen interlacing bundles of hyalinized colla

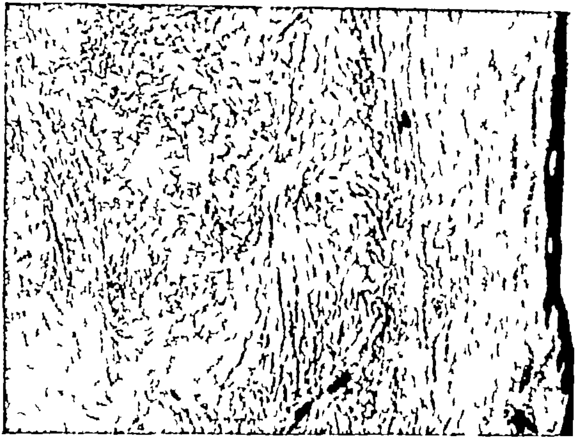

FIG 384 A true keloid excised twice in five years following an original removal of a papilloma by ligature around the base The epithelium is seen as a black band (out of focus) at the right border To the left of this is dense scar tissue which terminates abruptly with the greatly enlarged collagen fibrils constituting the true keloid. At the extreme left there is again ordinary scar tissue (Frantz V K Surgical Pathology *Nelson's Loose Leaf Living Surgery* 1 260 1941)

gen (Fig 381) Moderate vascularization in the early stages gives the keloid a red color and the tissue becomes white firm and relatively avascular at a later date. Elastic fibrils are usually absent The overlying epithelial layer is often atrophic and flat The keloid develops along the blood vessels. It may be formed as Unna believes by the adventitia of the blood vessels (Unna 1891) thus accounting for the branched spreading of keloids. Histological examination of keloids gives the impression of a slowly progressive infiltrative growth rather than a transformation of the surrounding tissue but it must be emphasized that both the microscopic picture of the hypertrophic scar and the keloid appear quite similar

The keloid usually begins as a thickening in the wound either early within fourteen days, or a number of weeks after the wound has healed It grows slowly and years may elapse before it attains maximum dimensions. It usually grows in the direction of stretching of the skin In some cases, such as keloids which develop following piercing of ear lobes, the tumor growth expands symmetrically Spontaneous involution of a keloid is rare in such cases, the scar may be considered to have been hypertrophic rather than keloidal

Hypertrophic scars become paler softer and less conspicuous with the passage of time (Fig 385) whereas keloids may continue to increase in size attaining enormous proportions in Negroes In Caucasians however keloids may resume the characteristics of a hypertrophic scar after a year or more and some authors have expressed doubt that true keloids are found in members of the white race

FIG 385

Hypertrophic scars of face resulting from burns.

(*Left*) Child, age 6 showing hypertrophic scars of face resulting from burns.
(*Right*) Same patient, age 22, showing spontaneous regression of hypertrophic scars.

The etiology and nature of these unusual methods of healing are not completely understood Sepsis, foreign bodies, imbedded hair follicles, inadequate approximation of wound edges, wounds sutured under tension and scars placed at right angles to the lines of tension of the skin all predispose to hypertrophic scarring (Fig 379) Areas such as the auricular and suprasternal regions are particularly predisposed to keloids Young individuals have a greater tendency toward hypertrophic scarring than older people whose skin has lost a great deal of its elasticity

Both local and systemic factors have been held responsible for the formation of hypertrophic scars and keloids. It is generally accepted that there is a congenital individual predisposition of the connective tissue to react to trauma with pathological formation of new connective tissue. The cause may be a burn a caustic agent, a cut, a surgical incision electrocoagulation inflammation of the skin such as acne furunculosis chicken pox or small pox vaccination Even a pin prick may determine the onset of a keloidal tumor A keloid described by Welander (1898) developed in the red spots of a tattooed scar and not in the blue ones.

Mowlem (1951) states that a proportion of hypertrophic scars contain foreign bodies which are not encysted. The foreign bodies are exogenous materials imbedded as the result of penetrating injuries, shreds of cotton gauze left in the wound at operation or buried sutures. In a considerably higher proportion of cases, the inclusions consist of lanugo hair follicles and sebaceous glands incorporated in the scar during healing

Glucksmann (1951) in support of the theory that buried lanugo hair follicles are a factor in the production of hypertrophic scars, mentions the presence of acne keloids which follow folliculitis. The acne keloid is characterized by the presence of hair fragments and a foreign body reaction

The inclusion of foreign particles is used by some members of the colored races to produce ornamental keloids which play a similar psychological role as tattooing among members of the white race (Lacassagne and Rousset 1931 Bohrod 1937) These keloids are produced by incising the skin in various areas of the body and preventing rapid heal

ing by rubbing soil ashes ground rice and irritating juices into the wound the procedure is repeated until a keloid of desired size is obtained Keloids may persist because the foreign bodies causing the hypertrophy are not resorbed. Scar hypertrophy and keloids tend to arise in sites covered by lanugo hair preferably in those regions where lanugo hair is being replaced by terminal hairs as for instance on the face and presternal region The amount of lanugo decreases with age because of its conversion into terminal hairs and because of atrophy of the hair follicles (Danforth 1925) Young people and women of white races as well as Negroes, tend to have less terminal hair and much more lanugo hair The possibility of including lanugo hair in wounds increases with the amount possessed by the individual Thus, to some extent the greater incidence of keloids in certain age groups races, and possibly in the female sex may be attributed to local factors, such as the greater availability of potential foreign bodies.

There are variations in the amount of buried keratin in individuals and also systemic variations in the amount of reaction resulting from such keratin This may account for variations in hypertrophic scarring in different individuals. In addition to variations in general systemic factors there also must be variations in local factors, for two scars in the same patient do not always produce similar and equal responses. Keratin-containing lanugo hair follicles and sebaceous glands may be buried beneath the skin surface in wounds. There is a greater likelihood of hair follicles or sweat glands being buried in patients with thick oily skin because of the larger number of such structures in such skin

The frequent finding that stable scars contain foreign bodies which are well-encapsulated and cause no reaction seems to oppose the theory that foreign bodies are responsible for scar hypertrophy some individuals may be more sensitive to the presence of foreign bodies than others.

Systemic factors seem to play a more important role in the causation of hypertrophic scars and keloids. In addition to observations that hypertrophic scars and keloids occur more frequently in the young and in Negroes, it has also been noted that certain endocrine disturbances, such as those occurring with pregnancy and thyroid dysfunction are associated with the formation of hypertrophied scar tissue Keloids have been found to contain more than normal amounts of estrogenic and pituitary hormones (Geschickter and Lewis, 1935) and have been induced in monkeys by estrogenic injections (Vargas, 1915). Jacobsson (1918) reported the case of a woman whose four year-old scar became hypertrophic during pregnancy

Bloom (1956) reported that a predisposition to hypertrophic scarring has long been recognized as a familial and hereditary trait. He examined the keloid histories of thirty one families, and studied the pedigrees of an Italian family with fourteen affected members in five generations. These pedigrees indicated that the predisposition to keloids is inherited according to a regular dominant autosomal mechanism

It is a common observation that patients who have not shown a previous tendency toward hypertrophied scars develop massive scars or keloids following severe burns. It has also been observed that subsequent trauma not related to the burn has resulted in keloid formation Young girls, following severe burns, repeatedly have developed hirsutism a phenomenon which is considered to be a manifestation of hyperadrenalism An initial increase in the urinary output of 17 ketosteroids was found in similarly injured victims of the Cocoanut Grove disaster for the first few days a decrease below normal value followed this finding the greatest hair growth appeared

in women who had exhibited a low urinary output of 17 ketosteroids.

Cortisone arrests fibroplasia in wounds and should therefore minimize scar hyper trophy during the period of administration of the drug Burn patients receiving substantial doses of ACTH showed little scar hypertrophy until cessation of the hormone therapy Hypertrophy then appeared simi lar to that seen in patients who had not received ACTH Our experience with ACTH, cortisone and Compound F in the treatment and control of hypertrophic scars and keloids has proved disappointing

Success in the treatment of keloids has been attributed to the action of hyaluroni dase when injected into the tumor mass. The enzyme is supposed to act by depolymerizing a portion of the ground substance of the skin thus producing softening and diminution in the size of keloids, the method has been unsuccessful in our hands.

Painful Scars

Wound healing is usually attended by a varying degree of pain which disappears after a few days. Pain sometimes persists for a few months or even years after healing Painful sensation may recur at var iable intervals after wound healing The epithelium of the scar may be tender to the lightest touch. Painful sensations and itch ing are frequent accompaniments of hyper trophic scars and keloids the patient is more concerned with these symptoms than with the disfigurement caused by the scar

The irritability of cutaneous scars may be partly due to the increased sensitivity of su perficial regenerating sensory nerve fibers which penetrating the scar have not ac quired encapsulated corpuscle endings. Such free and unprotected fibers react to irrita tion more quickly and easily than the more heavily protected fibers.

Leriche (1939) described non-myelinated fibers at the periphery of the fibrous portion of a scar There are few non myelinated fibers scattered through the cicatrix after six months. Myelinated fibers are found at the periphery of the cicatrix about the fifth week and all through it after the seventh month These fibers are tortuous, thicker than the normal fibers and in some cases are almost nodular

Medullated and non-medullated fibers ac companying strands of collagen are located immediately under the epithelium and ex tend parallel to it unlike normal skin where the fibers extend up into the epithelial layers between the papillae. Tiny terminat ing knobs or clubs of the fibers are consid ered by Leriche to be small neuromas.

The nerve nets and terminals subserving the sensation of pain in the skin are isolated from their neighbors in painful scars in stead of interweaving with them as in nor mal skin (Weddell 1941 Woollard Wed dell and Harpman 1940)

Nerve compression may occur following operation or injury if a sensory nerve becomes enmeshed in scar tissue This condi tion is frequently observed in the area of the supraorbital nerve as a result of scar tissue around the nerve at its exit from the supra orbital foramen and also around the infra orbital nerve at its exit from the infraorbital foramen Direct compression of a nerve trunk due to fracture may be caused by dis placed fragments of bone Digital pressure over the area corresponding to the compression of the nerve elicits a painful response the diagnosis is confirmed when a local anesthetic relieves the pain

THE REPAIR OF FACIAL SCARS

The results of surgical repair of a facial scar are difficult to predict and are varia ble Because the patient has the concept that scars can be removed it is necessary to explain that a deforming scar is replaced by an operative scar which at best may be only slightly visible. Disappointment will ensue if the patient is led to expect per fection All factors being equal two facial

scars excised and carefully sutured after excision with the same care and perfection of technique may result differently because of variable local and systemic factors discussed earlier in this chapter

Most scars, with the exception of keloids which continue to grow in tumor like fashion tend to soften become flattened and less visible with the passage of time. Improvement often continues through the years thus accounting for the fact that scars *resulting from lacerations in childhood* are often barely visible after the individual has reached adult life A follow up of the burn scars due to the atomic bombings in Japan showed that extensive wide hypertrophic scars gradually became flatter and softer over a four year period (Wells and Tsukifuji 1952) this confirms common observations (Fig 385) Hypertrophic scarring had disappeared or had decreased appreciably in size except in areas where infection foreign bodies contractures or abnormal skin tension were present

The disappearance of the tendency toward hypertrophic scarring particularly following burns, makes it advisable to postpone secondary repair for at least one year or until spontaneous improvement of the scars is observed. The progressive improvement of hypertrophic scars is hastened by massage and local application of heat.

Early repair of a traumatic scar should be avoided while the wound is still undergoing the various phases of wound healing A larger scar of a similar type may be the price paid for such an error We allow a period of a number of months to elapse before undertaking revision advising physiotherapy in the interim

The choice of a number of different techniques must be made after deciding to repair the scar Excision of the entire scar is feasible in adults due to the relaxation of the skin of the face the excessive tissue permits the repair of appreciable defects by direct approximation If the direction of the scar is unfavorable across a line of facial expression for example the direction should be changed. The Z plasty method can be employed to advantage in such cases (see Chapter 17) Multiple Z plasties can be used in the repair of long straight scars.

The repair of extensive scars presents special problems. A satisfactory method of treating a scar that cannot be repaired by excision and closure of the wound margins by direct approximation because of its large size is to shift the defect to a less conspicuous location by a flap of adjacent tissue (Fig 386). In some cases the defect can be transferred to an area which is not visible such as one behind the hairline or in the retroauricular region (see Figs. 882 886 Chapter 23)

Broad scars that have a scar type of epithelium improve with the passage of time their excision may result in a more disfiguring defect Repeated partial excision of the scarred area may be the method of choice in such cases. The location of the scar should be considered when the defect is to be repaired by either a local flap or a free skin graft In the repair of a scar of the upper eyelid which results in a secondary defect that cannot be closed with local tissue an excellent result can be achieved with a free full thickness graft of skin removed from the opposite lid. There are also other areas of the body where repair with a full thickness graft removed from the retroauricular region or from the base of the neck is extremely favorable an example of such a defect is one situated over the lateral wall of the nose

If tension is present it should be relieved by restoring an adequate surface of skin. The relief of tension will sometimes result in gradual resorption or softening of hypertrophic scars, in addition to relieving the deforming contractures Jobert (1849) and Denonvilliers (1856) stressed the importance of relieving tension by shifting local flaps into the area of tension

It may be necessary to excise the scar completely bringing the wound edges together

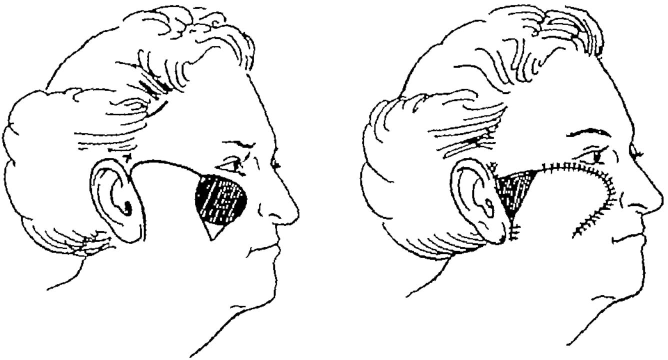

Fig 386 The principle of shifting the defect. A flap of skin comprising the full thickness of the subcutaneous tissues is transferred from over the parotid masseteric fascia to repair a primary defect. The secondary defect, shifted to the less conspicuous preauricular area, is repaired by means of a full thickness retroauricular graft.

by accurately placed sutures It may be desirable in some cases to excise only a portion of the scar in a depressed scar one may leave the cicatrix in position and suture the superficial tissues over it. In still other cases, where excision is inadvisable the abrasion technique may be employed.

Total Scar Excision and Repair

An ink outline of the scar previous to incision is a useful procedure. The scar on the surface of the skin is not as wide as the portion of the scar below the skin. The excision of scar tissue should therefore always be extended a few millimeters beyond the visible scarred area on the skin Failure to do this causes the skin edges to turn in due to lack of elasticity of the deep scar tissue. In order to obtain accurate apposition of both edges of the wound the two sides of the elliptical area of the scar should follow the same general curvature The incision should extend through the skin and subcutaneous tissues to below the level of the scar tissue the strip of scar tissue is then removed If the wound edges can be approximated without tension undermining is unnecesary undermining the wound edges is required however when tension is present. It is then important to close the wound layer by layer If the wound extends down through a superficial muscle layer or a deep fascial layer these structures should be closed by a first row of catgut sutures 4-0 catgut plain or chromic, is generally used for interrupted sutures (see Fig 68 Chapter 3) It is usually necessary to approximate the base of the dermis at the junction of the dermis and subcutaneous fat. Buried horizontal mattress sutures 4-0 or 5-0 catgut, are usually employed to bring the wound edges together to prevent dead space and to secure accurate approximation before placing the skin sutures proper Closely placed interrupted everting skin sutures are then used to accurately approximate the wound edges these are usually 5-0 or 6-0 silk or nylon sutures. They should be placed without tension at the same level in both edges of the wound in order that the surface of the wound edges are accurately approximated Careful im

mobilization of the area by a pressure dressing is necessary

Repeated Partial Excision of Scars
(Morestin 1915 Davis, 1929)

Partial excision may be preferable in very wide scars, where total excision and suture cannot be done without tension (Fig 387) Multiple repeated partial excision is indicated in areas surrounded by loose tissue. Subsequent operations are done at suitable intervals, provided that sufficient loose tissue is available and that distortion does not result distortion must be avoided Wide undermining of the surrounding skin is essential

Split Thickness Excision of Scars

This technique is employed in depressed scars (Poulard 1918) The epidermis and a thin layer of dermis are excised. The remaining dermis and scarred subcutaneous tissues are buried under the undermined sutured wound edges, thus correcting the depression (Fig 388) Split thickness excision of scars, followed by skin grafting is discussed in Chapter 18 (see Fig 158)

The entire scarred area can be used as a deep implant in depressed areas. The area is outlined by a circumferential incision and the wound edges are undermined. The scarred skin is left in the wound while the adjacent tissues are sutured over the scarred areas. An example of the use of such buried scar tissues is illustrated in Figure 389

Most of the sebaceous glands are situated superficially in the dermis close to the epidermis these structures are the possible cause of cyst formation Because scar tissue is devoid of sebaceous glands and hair follicles, fewer complications result than when normal skin is buried

The Abrasion Treatment

Desquamation of the epidermis to obtain a new epithelial surface is a procedure commonly used by dermatologists. Various corrosive and burning agents have been employed for this purpose Mechanical means have been developed in recent years to remove the epidermis and the superficial layers of the dermis with sandpaper either by hand sandpaper rolls (Iverson 1947).

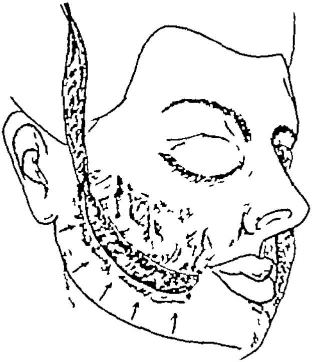

Fig 387 Partial excision of scar The excised area is within the limit of the scar The lower edge of the w and is undermined to release tension as indicated by the arrows

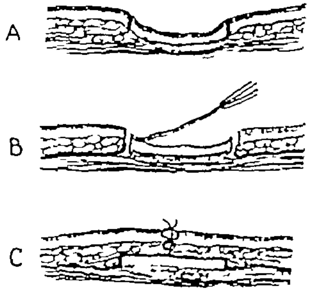

Fig 388 Split thickness excision of scar
A The scar is outlined by incisions
B The epidermal layer of the scar is removed
C The edges of the surrounding skin are approximated over the scar

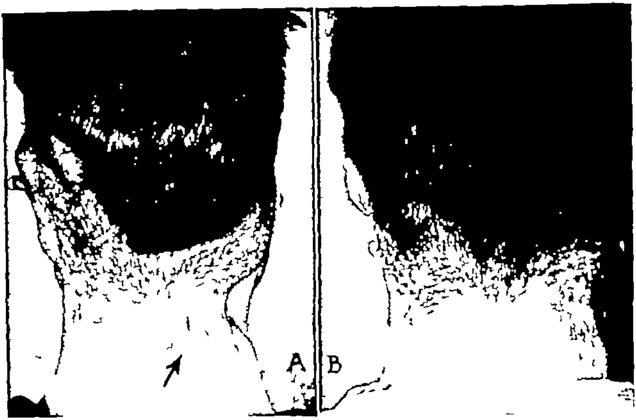

FIG 389

A. Depressed scar at the base of the neck caused by attempt to cut off patient's head The patient, a Greek soldier captured by guerillas, was subjected to amputation of both ears, the left ear by the teeth of his tormentors and the right ear by a knife. He was then stabbed 12 times through the chest with a bayonet and when he appeared to be still living an attempt was made to sever the head from the trunk. The knife sectioned the muscles of the neck down to the spine but did not sever the large vessels.

B Repair attained by inciting around the periphery of the scar and approximating the edges of the trapezius muscle and skin over the scar

surgical burs or wire brushes (Kurtin 1953) driven by an electric motor A similar result can also be obtained by using a scalpel or skin graft knife or a small electric dermatome and shaving off a layer of epidermis and dermis, as for a very thin Thiersch graft.

The abrasion treatment is used for smoothing irregularities of the skin such as elevated scars and superficial lesions and removing foreign bodies imbedded and tattooed into the dermis. Abrasion has also been employed successfully to remove the epidermis and the superficial portion of the dermis containing superficial pits, such as those resulting from acne chicken pox or smallpox.

The smoothing effect obtained by the abrasion treatment in deep depressed scars and pits can be accounted for in part by the phenomenon of inter island contraction (see Chapter 2) The generalized contraction of the abraded area in the course of healing by inter island contraction results in closing a number of pits and reducing the width of others. The abrasion treatment has also been used to obtain a smooth line of junction at the edges of a scar

The skin abrasion method has become useful to the plastic surgeon in the treatment of irregularities of the skin which require planing

The advantage of mechanical abrasion over chemical methods is the control of the depth to which the dermis is penetrated. This is not true when using corrosive chemical agents, for the degree of penetration cannot always be evaluated and the sensi

tivity of the patient's skin cannot be predicted. Peeling, a method to renew the epidermis, employed in the past particularly by unqualified practitioners, has resulted in burns of the face with tragic consequences: excessive tightening of the skin or hypertrophic scars and keloids.

Similar complications can occur with the abrasion treatment if the depth of penetration is not controlled. An area which has been abraded too deeply presents a problem similar to that of a donor area following the removal of an excessively thick skin graft. The number of epidermal elements remaining in the dermis of the area is inadequate to insure epidermal resurfacing. It is safer to remain too superficial in the dermis rather than too deep, particularly as superficially abraded areas can be treated repeatedly as indicated.

Prudence should be exercised in using the abrasion method in certain scarred areas, such as those resulting from thermal burns or x-ray therapy, which contain no hair follicles or sebaceous glands and therefore show a poor degree of epithelial regeneration.

Various Techniques of the Abrasion Treatment

SANDPAPER (Iverson, 1947). Various grades of water resistant sandpaper are supplied commercially and can be sterilized by autoclaving. The treatment is usually initiated with a rather coarse grade of sandpaper and completed with a finer grade. The sandpaper can be held in the hand, folded over ... skin of a major portion of the face may be abraded within a short period.

BURS. Kromayer (1925) used dental burs. We have employed a special olive shaped bur (De Kleine, 1951). A tendency to heat the area through friction is a disadvantage; the method is also more time consuming if a wide area is to be treated, for the abrading surface of the bur is small. Burs are satisfactory for small areas and particularly for hypertrophic linear scars.

WIRE BRUSHES (Kurtin, 1953). The abrasive action of the wire brush is more rapid, particularly when driven at a high speed (Fig. 390C, D). The brush tends to become clogged with abraded skin; this does not occur rapidly, however, and the brush can be cleaned or changed. One danger is a tendency to gouge the skin along the edge of the brush.

Methods of Anesthesia

General anesthesia can be employed where an extensive area of the face is to be abraded; regional and infiltration anesthesia can be employed for lesser areas. Ethyl chloride spray can also be used (Fig. 390A). The disadvantage of general anesthesia is that hospitalization is required. The ethyl chloride spray is a particularly convenient method because it is rapid, causes a stiffening of the skin in the area to be abraded and is an out-patient procedure. A spray of ethyl chloride is applied to the area to be abraded by an assistant, who also holds a small rubber bulb or air blower with which vaporization and therefore superficial freezing is

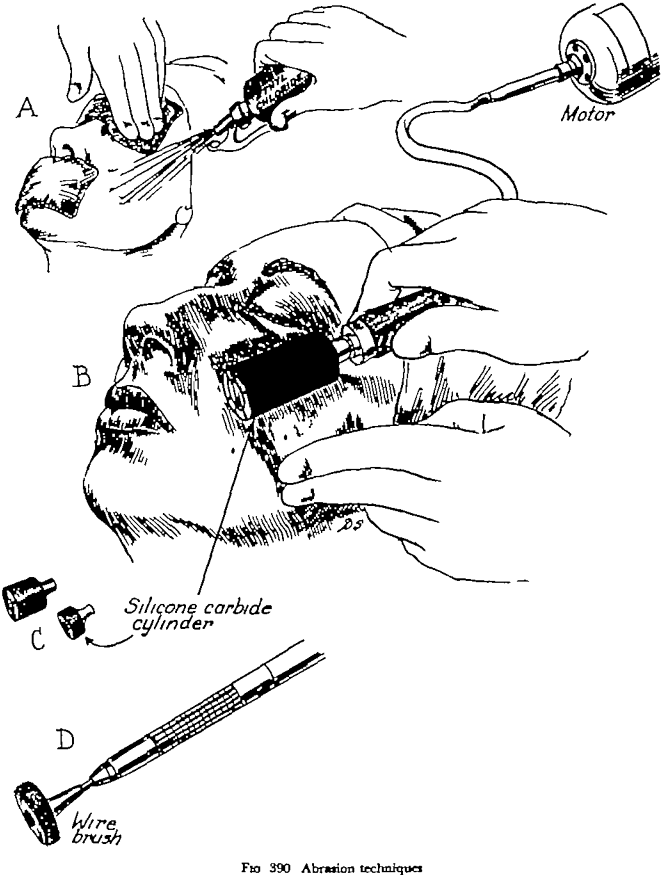

FIG 390 Abrasion techniques
A Illustrating the ethyl chloride spray method of obtaining local anesthesia for abrasion.
B. Abrasion by means of the sandpaper roll.
C and D Wire brushes used for abrasion

tivity of the patient's skin cannot be predicted. Peeling, a method to renew the epidermis employed in the past particularly by unqualified practitioners has resulted in burns of the face with tragic consequences excessive tightening of the skin or hypertrophic scars and keloids

Similar complications can occur with the abrasion treatment if the depth of penetration is not controlled. An area which has been abraded too deeply presents a problem similar to that of a donor area following the removal of an excessively thick skin graft. The number of epidermal elements remaining in the dermis of the area is inadequate to insure epidermal resurfacing. It is safer to remain too superficial in the dermis rather than too deep particularly as superficially abraded areas can be treated repeatedly as indicated

Prudence should be exercised in using the abrasion method in certain scarred areas, such as those resulting from thermal burns or x ray therapy which contain no hair follicles or sebaceous glands and therefore show a poor degree of epithelial regeneration

Various Techniques of the Abrasion Treatment

SANDPAPER (Iverson 1947) Various grades of water resistant sandpaper are supplied commercially and can be sterilized by autoclaving. The treatment is usually initiated with a rather coarse grade of sandpaper and completed with a finer grade. The sandpaper can be held in the hand folded over the index finger or can be rolled upon a gauze compress or flattened upon a piece of wood. The manual use of sandpaper for abrasion treatment however has been superseded by mechanical means.

SANDPAPER ROLL (Iverson 1957) These sandpaper rolls are mounted on electrically driven shafts (Fig 390B) the abrasive action is rapid and effective. This method has proved satisfactory in our hands because the skin of a major portion of the face may be abraded within a short period.

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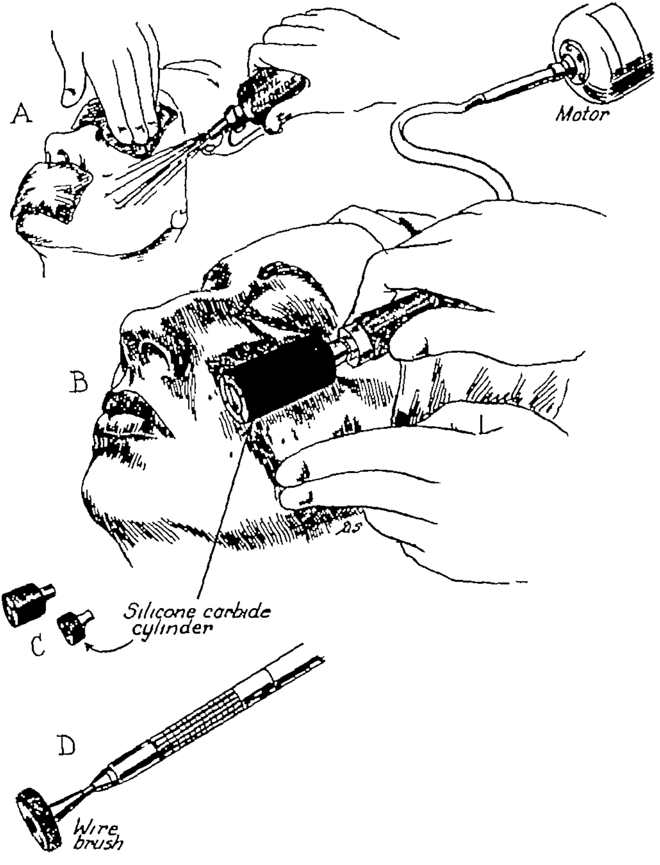
Postoperative Care of Abraded Areas

The advantages of the open treatment and of drying the area to obtain a protective crust under which epithelization progresses under optimum conditions is also stressed in Chapter 18 in connection with the post



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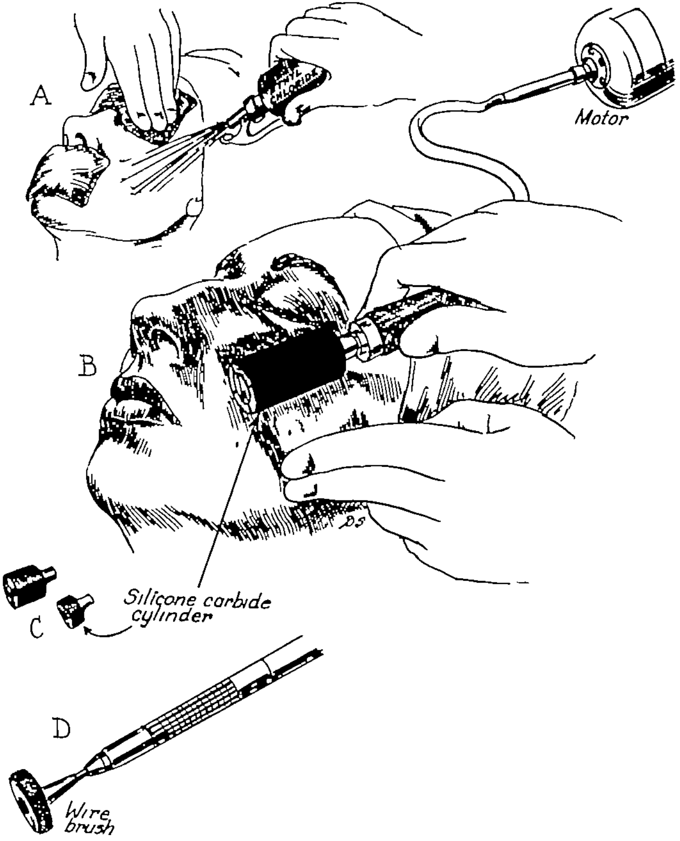

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operative treatment of donor areas of skin grafts. Warm dry air from an electric dryer is blown on the abraded areas until a fibrin clot forms on the surface of the wound. Continued drying transforms this fibrin covering into a protective crust. New epithelium grows under crusts which form and fall off spontaneously in 8 to 12 days leaving a delicate pink newly formed epithelial layer which is sensitive to trauma and sunlight for a few weeks after the operation

Repair of Tattooed Scars

Pigmented scars resulting from imbedded foreign bodies should be excised When a tattooed area is too extensive for excision and direct approximation the superficial foreign bodies may often be successfully removed by the abrasion method

Deeply imbedded foreign particles, as well as pigment particles which are placed deep in the reticular layer of the dermis, require surgical excision with closure by direct approximation or skin grafting

Small deeply ingrained tattoo marks that cannot be removed by simple curetting in the early stages or by the abrasion method should be removed with a trephine (Fig 391) A corneal trephine of adequate size is used to make a circumferential incision around the tatooed mark. The circumscribed area is then separated from its attachment to the subcutaneous tissue using a forceps and small knife After the circular area of skin has been removed it will be noted that the area has assumed an oval shape. This is due to the tension lines of Langer The oval area can usually be closed with one or more sutures of very fine silk. In larger trephine holes it may be necessary to excise a small triangular segment of skin at each end of the oval area to facilitate closure

To attempt closure by direct approximation in some areas may be inadvisable due to the tenseness of the skin In such cases a free transplant of a full thickness circular area of skin is used removing a circular

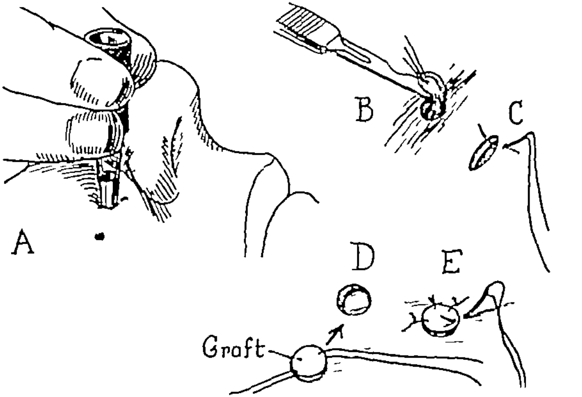

Fig 391 Excision of deep pits with a corneal trephine

A B and C Illustrate the removal of a small circular area of skin and direct closure by suture D and E An alternate method replacement of an excised circle of skin as a full thickness skin graft

graft from an appropriate donor area with a trephine as in the removal of the circular area of skin described above.

Compression Treatment of Scars

The treatment of hypertrophic scars by compression was advocated by Dupuytren (1839) who applied a continuous pressure dressing to flatten out red elevated scars The method is of some assistance in areas such as the forehead where adequate pressure can be maintained for a sufficient length of time by strips of foam rubber pads retained by adhesive tape.

Radiation Therapy of Scars

Many plastic surgeons are opposed to the use of radiation in the treatment of scars because of the radiation burns they have been called upon to treat. Radiologists feel that controlled doses of radiation are devoid of danger arguing that most radiation burns are due to indiscriminate and poorly controlled radiation therapy by unqualified practitioners. A review of the opinions of a number of radiation therapists who have had extensive experience in the treatment of scars follows

Freund (1913) was the first to use postoperative prophylactic roentgen treatment following surgery in 1909 He stated that a keloid should be treated with radiation before it is one year old because it gradually becomes less radiosensitive.

It is often necessary to decide whether irradiation alone should be given or whether one should combine excision of the keloid with pre- and postoperative irradiation Young keloids often respond to irradiation alone old thick and well-developed keloids usually require excision combined with irradiation.

In keloids of large size a preliminary partial excision of the mass may be indicated to reduce its size. Complete excision combined with radiation is done later

In surgery for carcinoma of the breast in non-irradiated cases, a proportion of cases develop hypertrophic scars, especially in the region of the anterior axillary fold hypertrophied scars, however are rarely seen in postoperative irradiated cases

The effects of radiation on normal skin are complex whether by x ray or radium and depend not only on the actual dosage but upon other factors such as duration of exposure and the interval between doses.

Radiation may produce three types of skin complications acute radiodermatitis chronic radiodermatitis and late effects (Levitt 1951)

Acute radiodermatitis follows the application of comparatively large doses of radiation within a relatively short space of time and results in faint pink erythema bright red erythema or erythema with blistering and deep ulceration depending upon the dosage applied to the skin

Chronic radiodermatitis follows the application of repeated small doses of radiation over a long period of time, usually many months or years, and is the typical occupational condition occurring in radiologists and industrial x ray and radium workers. The changes of chronic radiodermatitis are not mainly inflammatory as in acute radiodermatitis but are proliferative, consisting of a thickening and rigidity of the skin keratosis, fissures and eventually carcinoma which usually develops in a fissure.

The late effects of radiation are those which follow an acute radiodermatitis after an interval during which the skin may appear to be completely normal and healthy. These are pigmentation telangiectasis, scarring and skin atrophy and sometimes late ulceration The tissue becomes delicate and infection may follow even the slightest trauma These late effects are mainly atrophic and are in sharp contrast with the changes of chronic radiodermatitis which are principally hypertrophic and also present the hazard of eventual carcinoma.

Levitt (1951) describes four degrees of acute x-ray dermatitis the first is pink ery

thema the second a bright red erythema the third is characterized by blistering and the fourth by ulceration. He gives preoperative and postoperative radiation producing *first degree reactions*. He has not been able to trace a complaint of telangiectasis in hundreds of cases In the treatment of developed hypertrophic scars Levitt felt justified in increasing the dosage to second degree reactions and even to repeat these once or twice A few telangiectases have resulted in such cases but they have been isolated and not of the unsightly bright red network variety In an experience of over a thousand cases, Levitt has observed only one case where radiation treatment applied for hypertrophic scars, has resulted in an ulcer and *feels that a first degree reaction is safe* and may be repeated once after a proper interval Second degree reaction should not be given at all where the cosmetic result is the paramount consideration unless the case is such that a few telangiectases would be a small price to pay for the resolution of a very unsightly scar

Levitt purposely refrained from giving dosage in physical units, because the effect of a given physical dose of radiation varies to some extent with the field size to which it is applied even if other factors are kept constant. The *correction factor* obtained from the calculation of the exposed area is also an essential factor in dosage such a calculation however becomes virtually impossible when dealing with a very irregular area The dosage generally recommended in preoperative and postoperative treatment employing the technical factors described varies between 525 to 650 r

If a moderate dose of radiation is applied to normal skin for example 600 r the principal dermal effects are in the capillaries and the smaller arteries and veins. The endothelium is seen to swell very soon after the delivery of the dose Leukocytes appear in the irradiated area and there may be some diapedesis of red cells. Marked dilatation of the capillaries occurs and new capillaries are opened up a number of hours after irradiation. Thrombi form in the smaller vessels, due probably to endothelial damage. These early changes are followed to some extent depending upon the dosage by thickening of the endothelium and narrowing of some vessels and obliteration of others. The vascular effects are mainly active *from 7 to 14 days after the irradiation.* Degenerative changes are observed in the sweat glands and in the hair follicles coincidentally with the vascular changes.

Radiation tends to prevent scar hypertrophy (1) by inhibiting early epidermal proliferation and thus lessening the risk of forming endogenous foreign bodies, and (2) by reducing the vascular supply and inflammatory *cellular infiltration of the dermis.* When radiation is applied to the skin through a perforated grid vastly greater doses of radiation can be tolerated than when the rays are applied to the same area uniformly The probable explanation is that when the volume of tissue irradiated is small the reparative changes which occur in adjacent healthy tissues may be much more effective If the volume irradiated is small enough for example a narrow scar line any clinical dosage may represent only a small fraction of the tolerance dose and good repair would be obtained even with a comparatively large dosage

The term radiation refers equally to x rays and to the gamma rays of radium. The technical advantages of x rays are so great that these are now employed almost to the complete exclusion of radium for the treatment of keloids and hypertrophic scars.

The volume of irradiated tissue is kept *as small as possible limiting the area exposed* on the surface by cutting thin layers of sheet lead accurately exposing only the area involved and protecting normal skin by using a ray of minimum penetrating power Levitt used a ray produced at 50 to 80 kv with minimum filtration and the shortest possible treating distance 5 to 12 cm all of which factors tend to reduce the

penetrating power In order to diminish the distance between the tube and the treated tissue he found it necessary to redesign the standard tube mountings.

The dose to be given is adjusted to produce a faint erythematous reaction a proper interval is allowed before a second application of the same dosage The interval is not less than two weeks for very narrow areas as in the preoperative and postoperative treatment but may be as long as two or even three months in larger areas such as keloids. The exposure should be made about a week before the operation in order that the effects of the x rays are well-established by the time the healing processes have reached the stage at which hyperplasia is likely to occur

The experience of most surgeons and radiation therapists indicates that the best results are obtained from a combination of preoperative and postoperative irradiation Postoperative radiation should be initiated as soon as practical after the operation. X irradiation requires about 7 to 14 days after the exposure to be effective. Early hypertrophic changes may occur before the effects of the irradiation are obtained for this reason *the combination of preoperative and* postoperative treatment is more effective.

In the treatment of well-developed scar hypertrophy a single exposure suffices if the thickening is bright red and recent. The standard dosage may be increased slightly if the scar is greatly raised above the surface and if the skin itself is not submitted to higher dosage When the thickening is less recent or pale, the application of a higher dosage of radiation may be essential. The individual case must be carefully evaluated to justify such an increased dosage.

In Levitt's opinion techniques in which radiation is applied in small weekly doses or in repeated fractions at intervals are unsatisfactory in the treatment of scars. If the dosage is sufficient to produce the required vascular changes, it cannot be repeated weekly and if it is insufficient to produce these changes, it is of no value Many radiotherapists who for years irradicated hypertrophic scars with the technique condemned by Levitt would disagree with him yet during the war Levitt showed that his technique was at least successful and demanded fewer treatments

Hypertrophic tumor like keloids require surgical removal In this type of keloid it is preferable not to excise the keloid completely leaving a strip of keloidal tissue at the edge to avoid involving normal surrounding tissue in the operative procedure and risking extension of the keloid into normal tissue. Closure should be accomplished without tension and skin grafts should be used to relieve tension if necessary Skin sutures can often be avoided, using buried sutures of either silk or catgut. A continuous intradermal type of suture can also be employed The reason for avoiding external skin sutures is that marked keloidal reaction is frequently seen at the point of placement of the sutures. Such cases should receive preoperative and postoperative radiation

The technique we have employed is that established by Lenz and Okrainetz (1957) depending on the size and thickness of the scar *a surface dose of 500–600 roentgen* units (80–100 KV) without or with 1–2 mm aluminium filter is given one week before operation An interval of one week previous to operation is allowed in order that the radiation effect is well-established before hyperplasia of the healing scar tissue is

A B

FIG 392. Excision of keloid and skin grafting
A Typical large keloid.
B Postoperative appearance after excision, radiation and skin grafting

likely to occur. The line of incision is accurately outlined and the surrounding healthy skin is protected by a shielding lead foil or plastic made of 87 per cent bismuth subnitrate and 13 per cent lanolin. The dose of radiation of 500 to 650 roentgen units is repeated after the operation as soon as practical because this application assures an adequate dosage and also because the surgeon may have been obliged to make incisions outside the previously radiated field.

For the treatment of well-established well vascularized keloids that are not to be excised, low kilo-voltage is used with minimum filtration and short target skin distance. Intervals between doses should not be less than two weeks for small areas, and up to two months for larger areas. A dose of 100 roentgen units is given and repeated, if necessary, in two weeks. The total dosage over a period of six months should not exceed 2000 roentgen units.

Another method employed by us in large keloids consists of excising the mass, irradiating the resulting raw surface and applying a skin graft on the following day (Fig. 392).

17

SKIN FLAPS

The pedicled skin flap is a portion of skin and subcutaneous adipose tissue which is raised from its bed but is left attached to the surrounding skin at a selected location on its periphery The vascular supply of the flap is maintained through this pedicle until new vessels from the host bed grow into the un dersurface of the flap Pedicled flaps may be obtained from tissues adjacent to the wound (local flaps) or from a more distant region (distant flaps) They may be used singly or in combination with other flaps depending on the location and the size of the defect.

Indications

Flaps are used when added thickness of the subcutaneous tissue is required to restore contour also for reconstruction in full thick ness defects of the cheek or the nose and when the recipient bed is unsuitable for a free skin graft. Since skin flaps carry their own blood supply through the pedicle of the flap they may be applied over poorly vascu larized areas they are less likely to change color or to contract.

Limitations

Additional scar lines and defects may re sult in a disfiguring secondary defect. The thickness of the flap may be an advantage in some instances and objectionable in others pedicled flaps from a distant donor site, placed over the superficial muscles of ex pression for example are too thick to per mit expressive movements. Problems may arise when a flap is transferred from a dis tance. The transfer of a tubed pedicled flap from the abdomen to the face requires an initial attachment of the flap to the wrist, the detachment of the flap from the ab- domen and the immobilization of the upper extremity in proximity to the face before transferring the flap to the face. Multiple operations a long period of hospitalization and a painful posture during transfer are factors which may detract from the useful ness of distant flaps. The foreign appear ance of skin which has been transferred to the face from a distant donor site is a fre quent objection

Vascularization of Flaps

When a flap is raised and shifted to its new position nourishment is dependent upon the blood supply through the pedicle until new blood and lymphatic vessels have grown from the recipient bed into the under surface of the flap The presence of an ade- quate arterial blood supply is therefore an important consideration in designing a flap Veins in the pedicle are as essential as ar teries since venous congestion may result in necrosis of the flap Dieffenbach (1833) impressed by the fact that inadequately vascularized flaps become blue, advocated sectioning some of the larger arteries enter ing the pedicle of the flap in order to im prove the venous return from the flap by diminishing the arterial blood inflow Many of his contemporaries, among these Blandin (1836) and Serre (1842) opposed this errone- ous precept.

FIG. 393. Example of narrow pedicled scalp with great flexibility for reconstruction of the eyebrow.

The vascularization of flaps is proportionately greater in children than in adults; precautions should be taken in older individuals to be certain that the proportions of a flap are adequate to ensure survival.

The distribution of the blood vessels in some areas permits including a vascular bundle within the pedicle of the flap and preparing a *longer and narrower flap*; a narrow pedicle offers greater flexibility to the flap, facilitating its transfer (Fig. 393). Incisions outlining a flap should follow the general direction of the blood vessels of the area as closely as possible.

Sharp angles at the corners of flaps are often designed to facilitate closure of the donor area; they should be avoided if possible, however, because sharp angles of skin are subject to ischemic necrosis. This complication can be accounted for by the pattern of the vasculature of the skin. In the subepidermal layer of the dermis, the vessels of the dermal plexus terminate in a series of capillary loops; these ensure the nourishment of the epidermis, which is devoid of blood vessels. The vessels of the dermal plexus are richly anastomosed; the terminal capillaries are not. When the angle of the flap is acute, the anastomotic pattern is interrupted and the tissue is inadequately irrigated. Necrosis usually begins in the nonvascular epidermis. It is advisable, therefore, to round the corners of the flaps slightly.

Incisions outlining the flap should be extended to the deep fascia whenever possible and the flap should be raised by separating the fat from the fascia by sharp dissection. Excess adipose may be carefully trimmed from the undersurface of a flap. Braithwaite (1950) demonstrated that the dermal and subdermal plexus appear to be the most prominent features of the vascular system of a tubed pedicled flap. A thin pedicle is just as viable as one containing all of the adipose tissue.

The arterial supply is curtailed and the venous drainage is limited when the skin and subcutaneous tissues are severed in the preparation of a flap; the pedicle of the flap must be adequate in width to insure adequate arterial blood supply and venous drainage. Cyanosis implies stagnation of blood in the dermal and subdermal plexuses, and occurs as a result of the vascular imbalance if the resistance to vascular outflow *at any point in the flap exceeds the* arterial pressure. The dense network of vessels of the dermal plexus helps to equalize the arterial pressure throughout the length of the flap in the manner of a reservoir. An adequate venous drainage is essential when blood is thus pooled in the dermal plexus.

A pedicle flap usually dies in cyanosis, not in pallor; venous inadequacy appears to be the primary mechanism in cyanosis of the flap. Fontaine and Pereira (1937) showed that gangrene of limbs of animals could be produced only when the venous drainage was completely blocked. The practical conclusions of these findings are that the dermal and *subdermal plexuses appear to be the* most important components of the vascular system of a pedicled flap. Fat may be removed prudently from the undersurface of

the flap a thin flap is as viable as one containing all the fatty subcutaneous tissue

Delay of Flaps

A flap is delayed when immediate mobilization and transfer may jeopardize its viability The vitality of a flap cannot always be assured when the length of the flap exceeds one and one half times the width of the pedicle, when the flap must be twisted or kinked to reach its destination when it must be cut counterwise to the direction of the blood vessels, or when the flap must cross the mid line of the body Delaying a flap acclimatizes the flap to a diminished blood supply: it also conditions and develops the vasculature of the pedicle of the flap in order that the vitality of the distal end of the flap is maintained The delaying procedure consists of cutting through the sides of the flap and leaving a small uncut bridge at the distal end (Figs. 394 395) The flap is raised from the underlying tissue by separating the fat from the deep fascia the edges of the flap are then sutured to the edges of the surrounding skin

This preliminary procedure results in an increase in the size and number of vessels, and a reorientation of the longitudinal circulation (German Finesilver and Davis, 1933) It is estimated that the new vascularization has reached its highest development by the seventh day

Flap delay was a routine procedure in Tagliocozzi s preparation of an arm flap for reconstructing the nose. The tubed pedicled flap (Filatov 1917 Gillies, 1918) is a delayed flap.

Dieffenbach and Lisfranc (quoted by Pierre 1851) made it a rule to unite flaps only after two or three hours in order to allow time for the flap to recover its vascularization and stop bleeding This delay had a serious inconvenience however after the introduction of anesthesia Blair (1921) emphasized the value of the delay procedure in preparing long flaps.

The advantages in delaying a flap are the avoidance of tissue loss from necrosis if the length of the flap is too great in proportion to the width. Longer flaps may thus be prepared The disadvantages are (1) an increase in the length of time necessary to effect the repair (2) subjecting the patient to an additional operation and (3) the ad

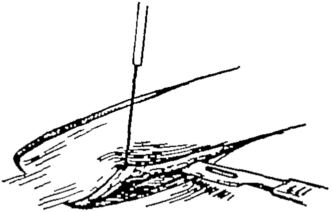

FIG 394 Delay of flap. Flap undermined. Bridge of tissue left at distal end

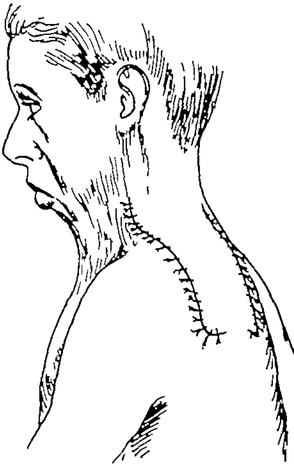

FIG 395 The delayed flap is resutured in original position after undermining The flap will be used to replace the scar tissue on the neck.

Fig. 393 Example of narrow pedicled scalp with great flexibility for reconstruction of the eyebrow

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Delay of Flaps

A flap is delayed when immediate mobilization and transfer may jeopardize its viability The vitality of a flap cannot always be assured when the length of the flap exceeds one and one half times the width of the pedicle when the flap must be twisted or kinked to reach its destination when it must be cut counterwise to the direction of the blood vessels, or when the flap must cross the mid line of the body Delaying a flap acclimatizes the flap to a diminished blood supply it also conditions and develops the vasculature of the pedicle of the flap in order that the vitality of the distal end of the flap is maintained The delaying procedure consists of cutting through the sides of the flap and leaving a small uncut bridge at the distal end (Figs. 394 395) The flap is raised from the underlying tissue by separating the fat from the deep fascia the edges of the flap are then sutured to the edges of the surrounding skin

This preliminary procedure results in an increase in the size and number of vessels, and a reorientation of the longitudinal circulation (German Finesilver and Davis, 1933) It is estimated that the new vascularization has reached its highest development by the seventh day

Flap delay was a routine procedure in Tagliocozzi s preparation of an arm flap for reconstructing the nose. The tubed pedicled flap (Filatov 1917 Gillies, 1918) is a delayed flap

Dieffenbach and Lisfranc (quoted by Pierre 1851) made it a rule to unite flaps only after two or three hours in order to allow time for the flap to recover its vascularization and stop bleeding This delay had a serious inconvenience, however after the introduction of anesthesia. Blair (1921) emphasized the value of the delay procedure in preparing long flaps.

The advantages in delaying a flap are the avoidance of tissue loss from necrosis if the length of the flap is too great in proportion to the width Longer flaps may thus be prepared. The disadvantages are (1) an increase in the length of time necessary to effect the repair (2) subjecting the patient to an additional operation and (3) the ad

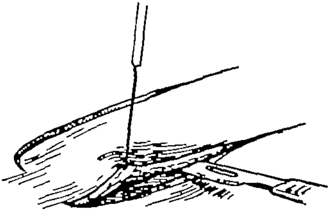

Fig 394 Delay of flap. Flap undermined. Bridge of tissue left at distal end

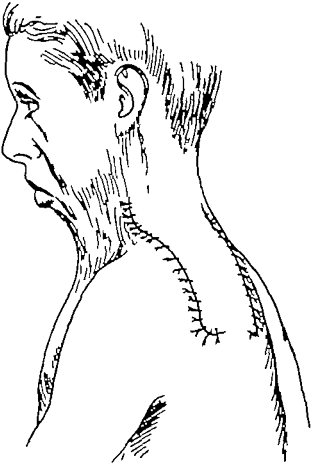

Fig 395 The delayed flap is resutured in original position after undermining The flap will be used to replace the scar tissue on the neck.

dition of scar tissue which follows preliminary undermining of the flap. Scar tissue is produced when a flap is raised from its bed not only in the bed in which the flap is replaced but also on the undersurface of the flap. The constrictive effect of scar tissue may defeat the purpose of the delay procedure and restrict the blood supply of the flap.

Outline Delay

The vessels supplying the skin in most areas of the body are branches of perforating vessels; adequate flap delay requires raising the flap from its bed. In the forehead and scalp, however, the vessels are peripheral and not branches of perforating vessels. An incision through the skin of the forehead or scalp outlining without undercutting the flap is an adequate procedure for the delay of the flap, avoiding the formation of scar tissue after undermining which results in varying degrees of stiffness of the flap.

LOCAL FLAPS

Skin immediately adjacent to the defect is usually similar in texture to that which was

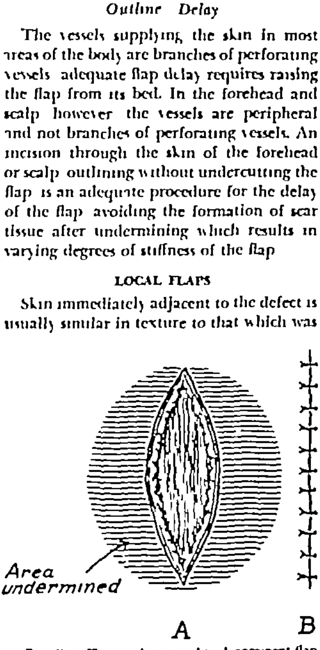

Fig. 396. The simplest straight advancement flap.
A. The surrounding tissues are undermined to facilitate approximation.
B. The wound edges are approximated without tension.

lost. If such tissue can be utilized the resulting repair is usually superior to that which could be effected with skin grafts or distant flaps, provided the scars produced by mobilization of the tissue are not conspicuous.

The shifting of local tissue is made possible by the natural elasticity of the skin which permits its adaptation to new positions. At no time should this elasticity be so abused that the flap assumes its new position under tension. A guiding principle in local flaps is the transfer of skin to a deficient area from an adjacent area where the skin is abundant.

Classification of Local Flaps

Local flaps may be classified as straight advancement flaps, transposition flaps, Z flaps and rotation flaps.

STRAIGHT ADVANCEMENT FLAPS. Advancement flaps were advocated by Celsus in the first century A.D. The method of Celsus appears to have consisted in a relaxation incision and a bipedicled flap advanced into the defect. From the available information (Gnudi and Webster, 1950) it appears that Celsus repaired defects with tissue from neighboring areas without rotating or separating the adjacent tissue from its underlying attachments. Franco (1556) was the first to describe a straight advancement flap to close a cheek defect by dissecting the flap from the underlying structures. Larrey used advancement flaps from the cheeks to reconstruct a nose. Advancement flaps were widely used by Lallemand, Roux, Roland, Chopart, Lisfranc and Gensoul who referred to them as "lambeaux par glissement" (sliding flaps) or also as "autoplasty by the French method."

The simplest type of straight advancement flap is created (Fig. 396) in the procedure of undermining or "undercutting" the edges of a wound and then approximating the wound edges. Both edges of the wound being undermined are mobilized toward the wound. When only one of the

edges of the wound is mobilized means must be found to further facilitate closure of the wound by releasing tension

The straight advancement flap depends for its mobilization upon separating the subcutaneous layer from the underlying fascia and the skin of the flap from the surrounding skin the elasticity of the skin and subcutaneous tissue permits stretching and shifting the tissue to a new position

When a straight advancement flap is shifted forward two folds of skin are formed in the adjacent tissue near the base of the flap. These folds of skin are removed by excision of a triangle of tissue lateral to the base of the flap on each side (Bürow 1838) and further advancement is thus made possible (Fig 397*B*) It is often possible to design the straight advancement flap so that it is wider at its base than at its distal end (Fig 398) as the flap is advanced a relatively larger amount of tissue is introduced *into the defect also releasing tension*

The straight advancement flap is of value only in regions where the skin around the defect is loose and abundant. Examples of such regions are the eyelids lips cheeks and neck particularly in older individuals Where the skin is tightly bound down to the underlying tissues attempts to advance flaps under tension may result in widening the scar a complication which may reproduce the original defect.

Further stretching of the flaps can also be obtained by cutting across the flap at right angles through the superficial fascia or the fatty tissue on the undersurface of the flaps. Such incisions are hazardous, however and can be done only in such well vascularized areas such as the scalp (see Fig 498 Chapter 20) Longitudinal incisions can also be made on the undersurface of the undermined tissue to facilitate the closure of a defect by direct approximation a method which is employed in the closure of an abdominal defect following the raising of a tubed pedicle flap

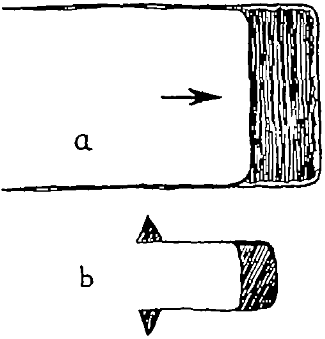

Fig 397 The straight advancement flap is made possible by parallel incisions to free the flaps (A)

Triangles of skin may be excised on each side of the base of the flap to facilitate the advancement (B)

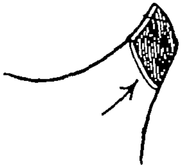

Fig 398 Straight advancement flap Note that the flap widens progressively toward the base.

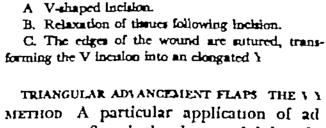

Fig 399 The V Y advancement technique

A V-shaped incision.

B. Relaxation of tissues following incision.

C. The edges of the wound are sutured, transforming the V incision into an elongated Y

TRIANGULAR ADVANCEMENT FLAPS THE V Y METHOD A particular application of advancement flaps is the closure of defects by

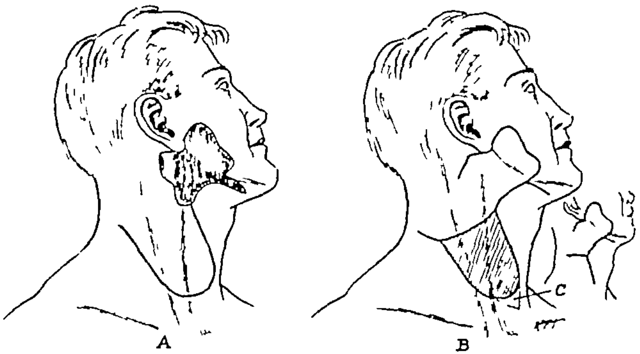

FIG 400 Example of transposition flap
A Outline of flap.
B. Transfer of flap to the defect.
C. Closure of the secondary defect by the V Y method

the V Y method (Wharton Jones 1817) The principle of this method is to transform a V into a Y by suture after advancing the skin on each side of the V (Fig 399) This closure permits the advancement of the flap situated between the branches of the V The V Y principle is used extensively in plastic surgery to elongate structures such as the columella for example (see Fig 668 Chapter 22) it is also used for direct closure of secondary defects demaining after the mobilization of flaps.

TRANSPOSITION FLAPS. A flap may be raised at an angle from the defect in an area where skin is abundant (Fig 400) The flap of neighboring tissue should be submitted to a change of plane whenever possible for example a horizontal defect should be closed by means of a vertical flap closure of the secondary defect by approximation is made possible without disturbing the repaired area the tension of the approximating sutures being placed along a direction different from that of the defect The greater the angle at which the flap is taken the easier will be the secondary closure The secondary defect can be closed by direct approximation when the surrounding tissue is loose. If this is not possible a skin graft or secondary local flaps should be employed.

BIPEDICLED TRANSPOSITION FLAPS. This type of transposed flap is useful when its mobility and flexibility can be increased by a narrow pedicle in which a vascular bundle is incorporated and when the flap undergoes a change of plane in its transfer as in the visor flap. A long flap of this type may be mobilized since the blood supply from both ends is assured (Fig 401). Bipedicled flaps may be shifted locally but are classified as distant flaps when extended over an area of intact skin

Local bipedicled transposed flaps should not be used indiscriminately on the face because additional scars and secondary contraction are produced by the healing of the relaxation incisions. These flaps are employed with satisfactory results however in other types of deformities For example large cicatricial areas of the scalp can be reduced in size by advancing two lateral flaps and leaving two smaller defects on

each side (Fig 402) the hair-bearing scalp flap divides the scarred tissue rendering the bald area less conspicuous Bipedicled scalp flaps have also been employed in large cranial defects to control cerebral herniation The hammock neck flap is useful in shifting skin from the neck to repair large bilateral defects of the lower portion of the face (see Fig 840 Chapter 23)

THE Z PLASTY TECHNIQUE. These are transposed triangular flaps each flap at an angulation of approximately 30 to 60 degrees assumes the position formerly occupied by the other If the angle of the flap is less than 30 degrees, it is too narrow and its blood supply may be endangered the flap lacks sufficient mobility if the angle is more than 60 degrees. The transposed triangles should be raised from the underlying tissue to obtain sufficient mobility and to effect transposition without tension.

The Z plastic operation is one of the most satisfactory and frequently employed procedures for the correction of scar contractures and the replacement of the misplaced tissues. Denonvilliers (1856) employed the principle of the Z plastic for the correction of an ectropion of the lower lid the procedure was also described by Szymanowski (1870) Piéchaud (1896) used Z transposition flaps for the release of axillary contractures and Morestin (1914) for scar contractures of the fingers. Davis and Kitlowski (1939) reviewed their experience with the use of Z plasty The monograph by Limberg (1946) contains a dissertation on the geometry of the Z plasty procedure

Z transposition flaps are useful for breaking the lines of tension in a recurring scar line or in elongating such a line (Fig 403) and they provide a satisfactory method of eliminating the linear contractures frequently seen following burns. Z transposition flaps are the classical method for correcting scar webs surrounded by healthy tissue such webs are seen on the face around the eye (epicanthus) and within the nares, around the mouth or on the neck

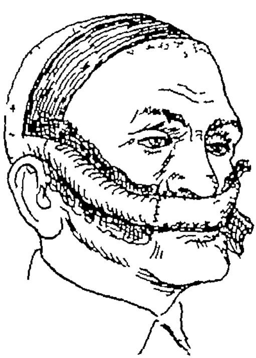

Fig 401 Visor flap to restore hairbearing skin to the upper lip A long flap is used, incorporating the superficial temporal vessels on both sides.

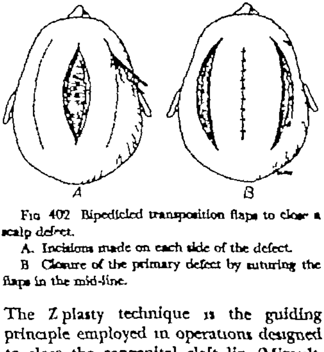

Fig 402 Bipedicled transposition flaps to close a scalp defect.

A. Incisions made on each side of the defect.

B Closure of the primary defect by suturing the flaps in the mid-line.

The Z plasty technique is the guiding principle employed in operations designed to close the congenital cleft lip (Mirault, 1868 Hagedorn 1884 LeMesurier 1949).

Z transposition flaps can be *employed* only with tissue which possesses an adequate blood supply When a wide area is scarred the Z transposition flap is helpful only in combination with a skin graft or another skin flap

When a scar line is to be elongated, the bases of the triangular flaps should be equal

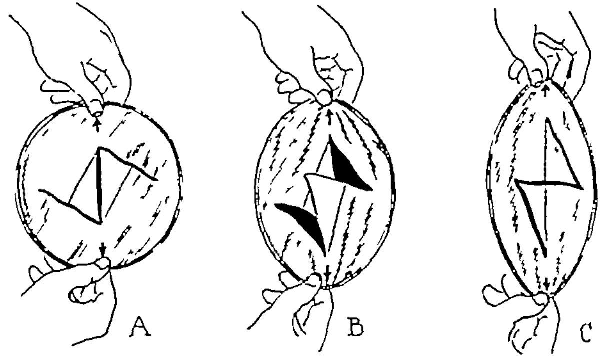

Fig. 403. The Z plasty technique

A. Arrows indicate the direction of elongation; the Z incision is indicated.

B. Illustrates the preparation of the transposition of the Z-flaps

C. Elongation obtained by Z-plasty technique

(Figs. 403 to 403 after Lamberg 1946)

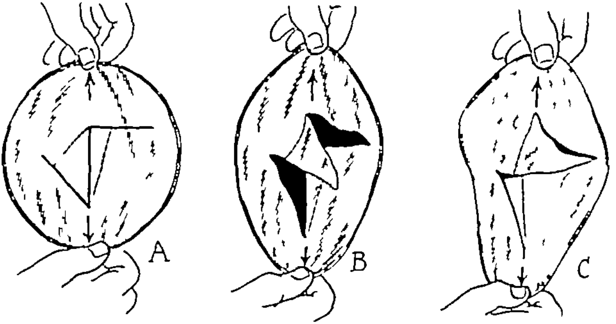

Fig. 404. The Z plasty technique

A. Lines of incision; arrows indicate direction of elongation

B. Elongation preparatory to Z-plasty

C. Elongation obtained

and the incision lines parallel as shown in Figure 405. Unequal triangles are permissible if one border of a defect is shorter than the other and requires elongation. The method is feasible only if one end of the incision is free, as with the lip or eyelid. It is an especially useful method to restore the continuity of the vermilion border of

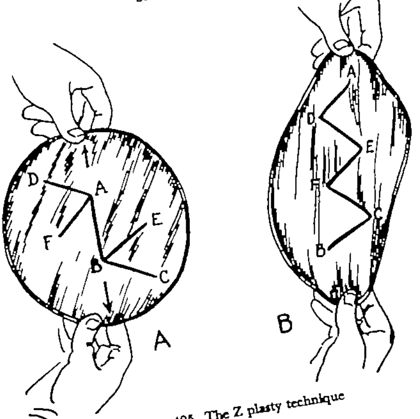

Fig 405. The Z plasty technique

A. Multiple incisions.
B. Elongation obtained.

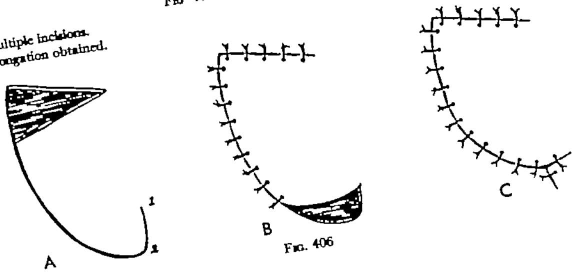

Fig. 406

A. Swinging-rotation flap
B. The counter incision 1–2 permits swinging the flap
C. The secondary defect is closed by the V Y method

the lip One incision is made almost at right angles to the border of the defect while the other forms a more acute tri angular flap (Fig 404) The width of the base of the triangle determines the amount of lengthening on the opposite side.

Multiple Z transposition flaps are em ployed to break up a long line of scar tissue (Fig 405) or to enlarge the circum ference of a circular scar

ROTATION FLAPS. By gradually curving the incision lines which outline a flap a gre degree of mobility is achieved for the can be rotated (Fig 406) The borr skin is rotated around a curve to clos defect without stretching the flap Th varieties of rotation flaps are the swi rotation flap (Esser 1917 Fig 406) a advancement rotation flap (Imre 192 407)

Swinging rotation flaps, with modifications, are the most usef

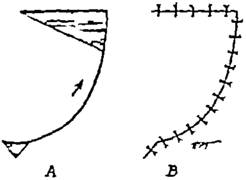

FIG. 407

A. Advancement-rotation flap.

B. Excision of triangle of skin at the base of flap facilitates advancement.

larization of the flap. The counter incision also facilitates closure of the secondary defect (Figs. 406C, 408B, C). A narrower pedicle may be used and greater mobility obtained when larger vessels, for example the branches of the superficial temporal artery or the external maxillary artery, are included in the flap. A variety of rotation flap, a cross between a rotation flap and a transposition flap, is shown in Figure 409.

The advancement rotation flap is based upon the excision of a Bürow triangle which

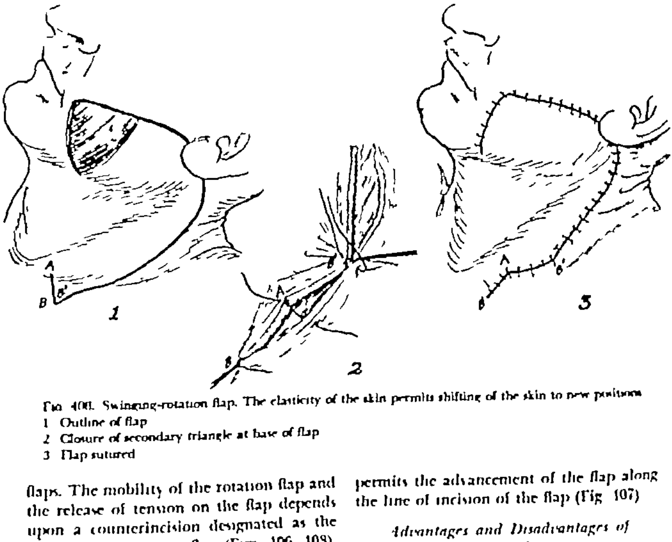

FIG. 408. Swinging-rotation flap. The elasticity of the skin permits shifting of the skin to new positions.

1. Outline of flap.
2. Closure of secondary triangle at base of flap.
3. Flap sutured.

flaps. The mobility of the rotation flap and the release of tension on the flap depends upon a counterincision designated as the "tail" of the rotation flap (Figs. 406, 408). The longer the incision, the greater the release of tension; the blood supply of the flap is impinged upon, however. In large rotation flaps, an adequate width of the pedicle permits a counter incision of sufficient length to insure mobility and vascu-

permits the advancement of the flap along the line of incision of the flap (Fig. 407).

Advantages and Disadvantages of Local Flaps

Two distinct advantages of local flaps are (1) the satisfactory matching of skin color and texture of the required tissue, the surrounding area, and the defect, and (2) minimum inconvenience is incurred by the pa-

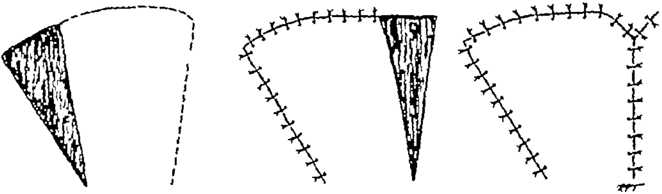

Fig. 409 Useful modification of the rotation flap intermediary between a rotation flap and a transposed flap.

A. Outline of flap

B Flap transferred.

C. The secondary defect is closed by the V Y method

tient, for the reconstructive procedure may often be performed in one stage, as compared with the slower multiple stage procedure and the discomfort which is associated with the transfer of pedicled flaps from a distant donor area.

The disadvantage of local flaps is the production of secondary scars resulting from the incisions outlining the flaps. An advantageous barter of tissues is achieved when these scars are minimized (see Chapter 16)

Technical Details in Local Flaps

Hemostasis should be complete in the recipient bed and on the raw surface of the flap. No dead space should be left under the flap for blood to collect. The flap is carefully sutured to avoid conspicuous scars, and is covered by a non-adherent dressing, with an absorbent cotton and gauze padding over the dressing In large flaps it is *advisable to* employ continuous suction under the flap to avoid hematoma. A small caliber non-collapsible polyethylene tubing and an electrically driven suction machine developing a pressure from 40–60 cm. of mercury are used. Occasionally buried cat gut sutures may be placed between the undersurface of the flap and the recipient bed (Fig 410) these sutures may also be employed to distribute tension over a wide surface in straight advancement flaps The region is immobilized by a slightly compressive dressing If the flap is located in the lower portion of the face immobilization should be sufficient to prevent movements of the mandible for activity of the jaw muscles may stretch the flap and detach it from its bed The use of inter-maxillary wiring is indicated in some instances to assure immobilization of the flap.

DISTANT FLAPS

Distant flaps are those which are conveyed over an area of normal skin on a pedicle which is later sectioned and returned to the donor area

The transfer of a forehead flap to the nose was employed during the nineteenth century and was known as the Indian method, after the technique employed in ancient India. Similarly the transfer of a pedicled flap from the arm to the face was referred to as the Italian method named after the surgeons of Renaissance Italy among them were the Brancas and Tagliocozzi

Distant flaps are indicated in extensive defects. The shifting of local tissue leaves a secondary defect which is difficult to close without distortion and tension distant flaps should be employed in such cases unless free skin grafting seems preferable

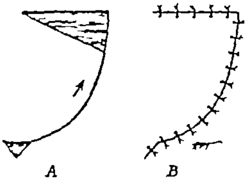

FIG 407
A Advancement-rotation flap.
B. Excision of triangle of skin at the base of flap facilitates advancement.

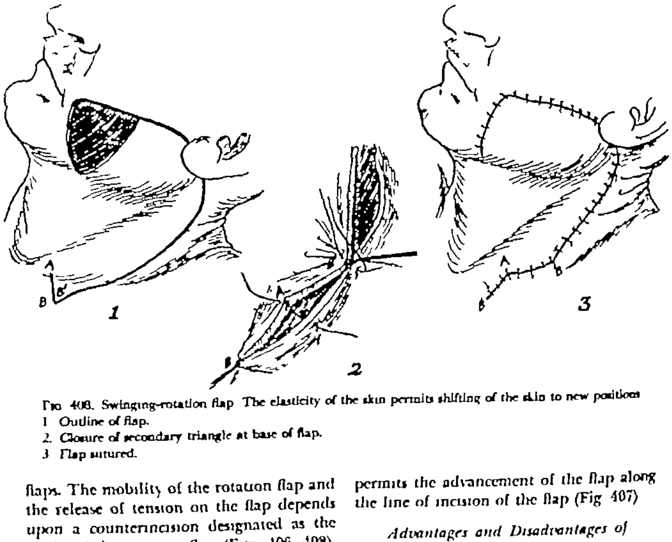

FIG 408. Swinging-rotation flap The elasticity of the skin permits shifting of the skin to new positions
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2. Closure of secondary triangle at base of flap.
3 Flap sutured.

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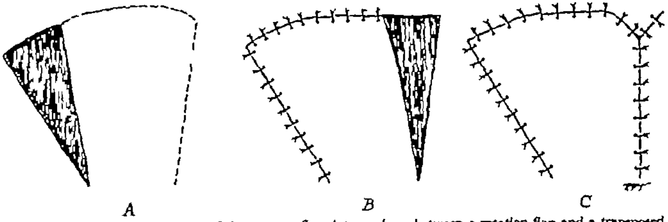

FIG 409 Useful modification of the rotation flap intermediary between a rotation flap and a transposed flap
A. Outline of flap
B. Flap transferred
C. The secondary defect is closed by the V Y method

tient, for the reconstructive procedure may often be performed in one stage, as compared with the slower multiple stage procedure and the discomfort which is associated with the transfer of pedicled flaps from a distant donor area

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DISTANT FLAPS

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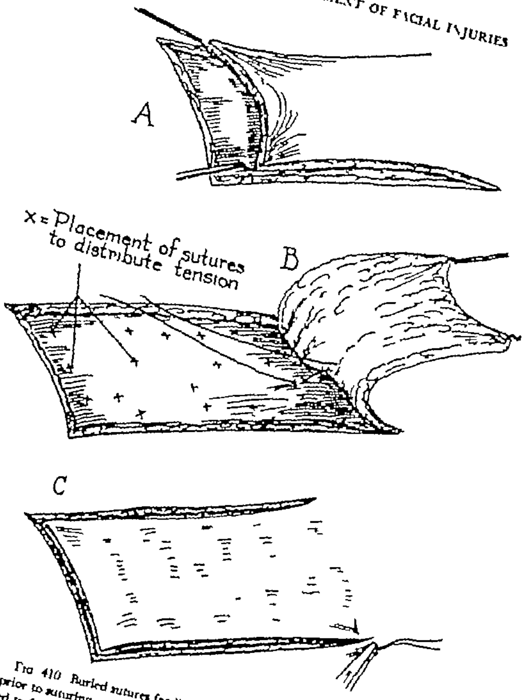

Fig 410 Buried sutures facilitating advancement flap
A Advancement flap prior to suturing
B Buried sutures placed to favor the advancement of the flap and distribute tension
C The flap is maintained by the deep sutures Suture of the edges of the flap is begun.

The advantages of flaps from a distant area are (1) the possibility of obtaining a flap of adequate size and (2) the concealment of the secondary defect by clothing in a region such as the abdomen

The distant flap has several disadvantages. The color thickness and texture may be unsuitable if the flap is removed from areas other than the head and neck multiple operations and extended hospitalization are necessary the risks are greater because of possible complications which may re in partial or complete necrosis. These advantages increase in direct proportion the distance between the donor area an the face

Open and Closed Distant Flaps

A distant pedicled flap is referred to as an open flap when it is raised and trans-

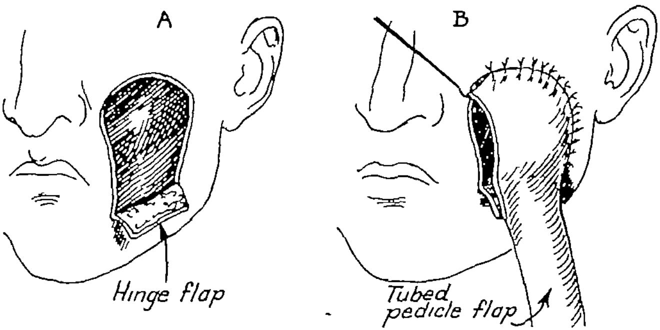

Fig 411 Use of a hinge-flap of skin adjacent to the defect to cover the raw surface of the flap
A. Defect receiving flap.
B Hinge-flap raised from the edge of the defect. This procedure increases the surface of the recipient site and also covers the raw surface under the flap

ferred to the defect, the intermediary portion between the defect and the base of the pedicle being left uncovered by soft tissue. A closed pedicled flap is obtained either (1) by tubing the skin flap or by covering the intermediary raw area (2) by another flap or (3) by a skin graft. The hinge-flap method (Converse, 1948) consists of turning back a flap from the side of the defect and applying the raw surface of this flap to the under surface of the open flap thus eliminating the exposed area (Fig 411)

Direct and Indirect Transfer of Distant Flaps

A skin flap from a distance may be transferred directly or indirectly from the donor site to the recipient site. Direct transfer of the flap to the defect is feasible when the flap is brought in contiguity with the defect for example, when a flap is long enough to be transferred to the face directly from the chest or the back. It is possible to effect a direct transfer of the flap if the defect can be approximated to the donor site of the flap for example, in repairing a defect of the forearm the upper extremity may be placed in direct contact with the abdomen for the transfer of an abdominal flap In the restoration of facial defects, a direct open flap from the arm to the face is an example of such a transfer The distance between the facial defect and the distant flap may be shortened by positioning the face properly for example in the transfer of an acromio-thoracic tubed pedicled flap to the face the head may be inclined toward the flap during the period of transfer to diminish the distance between the flap and the face.

In the direct transfer of the flap the outline of the flap is traced on the skin with ink and an incision is made along it. The distal end of the flap is then raised and the fat is removed from the underlying tissue by sharp dissection The flap now ready for transfer is anchored in the recipient bed by a few tacking sutures. It is often necessary to approximate the deep layers of the fat before suturing the skin The skin edges are united with fine interrupted sutures. The pedicle is sectioned and returned to its former position when the blood supply from the recipient bed is established usually after a period of f een to twenty-one days.

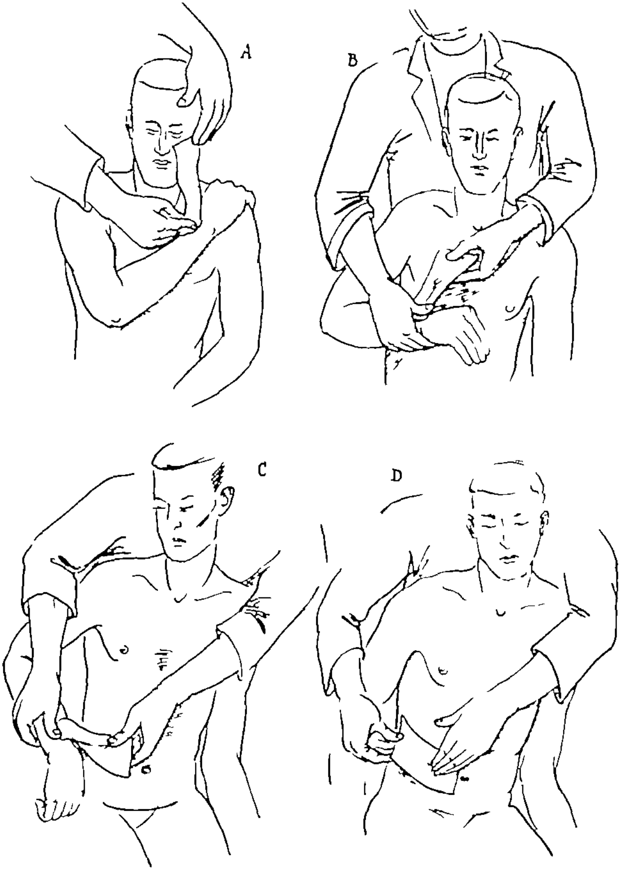

FIG. 412 Designing and planning a flap from a distance

A A cloth pattern of the proposed flap is held in position, carried on the forearm and applied to the facial defect

B The cloth pattern, detached from the face maintained attached to the forearm, is moved downward toward the abdomen.

C The upper extremity is placed into the position it will assume when the flap is attached to the fore arm.

D The cloth pattern of the proposed abdominal tubed pedicled flap is applied to the skin of the abdomen in the position of the future flap.

In indirect transfer a flap may be migrated in steps from a distant area to the face, or may be carried on the upper extremity These techniques are discussed later in this chapter

Designing the Skin Flap

The future flap is designed after the extent of the true defect has been determined (see Chapter 14) A pattern is cut to the approximate shape of the defect and also in the position of the flap required as a carrying pedicle as though the operation of flap transfer were completed (Gillies, 1932) The pattern is then spread over the donor area and the shape, size and angle of transfer are thus established (Fig 412)

The Tubed Pedicled Flap

After two parallel incisions have been made the flap can be closed by tubing the skin and suturing the skin edges, forming a bipedicled flap referred to as the tubed pedicled flap (Fig 413) The tubing of the skin flap is a relatively simple procedure for a flap of skin which remains unsutured tends to become rolled upon itself and to form a tube.

Tagliocozzi in delaying an arm flap prepared for nasal reconstruction maintained the separation of the flap from the underlying tissue by interposing a layer of linen the flap then progressively assumed a tubed shape. Burian (1955) has cited Dieffenbach s (1845) method of tubing the skin Filatov used the tubed pedicled flap on September 22, 1916 for the restoration of a lower lid which had been destroyed by carcinoma he reported the method in 1917 In a later French publication (1923) he named his flap plastie à tige ronde (the flap with a round stem) Gillies developed the tubed flap independently reporting it in 1918 and popularized the method in the Western World by defining the technique and its wide field of application

The tubed pedicled flap filled a need in the preantibiotic period when infection constituted a serious obstacle to tissue transplantation the closure of the flap by tubing rendered the method safe. The tubed pedicled flap a closed delayed flap remains a favorite method for the transfer of a large amount of skin from a distance for example from the abdomen to the face or neck. Its flexibility permits it to be twisted and turned to a degree. The length of the pedicle facilitates the transfer and renders the position of transfer a little more comfortable for the patient. The disadvantage of the tubed flap is the relatively long period of time required for its construction and transfer A lesser disadvantage is presented by the tubing· the flap tends to retain its rounded shape after transplantation to a flat surface When used over a rounded surface, such as the chin however this characteristic becomes advantageous.

The outline of the flap is drawn on the skin with ink its size should exceed the amount of tissue required for the repair as shrinkage occurs during transfer The flap is raised from the deep fascia between the two parallel incisions by sharp dissection (Fig 413*A*)· fat is trimmed from the undersurface if a thin flap is desired The flaps of thin individuals contain little fat whereas the adipose layer is often excessively thick in obese patients. Too little fat causes the flap to shrink, since a dead space is created within the tube. Strangulation of the pedicle occurs when excess fat is present it is necessary in such instances to resect some of the fat without destroying the subdermal vessels in the tube. A technique for this procedure is to resect the fat which protrudes from the side of the flap for the dermis contracts to a greater degree than the fat. If this procedure is not sufficient to eliminate compression within the tube additional adipose tissue is excised from the flap Avoidance of strangulation caused by an excess amount of fat in the tubed pedicled flap is an essential precaution for adequate vascularization and survival of the skin of the flap.

Prudence must be exerted when raising pedicled flaps, particularly tubed pedicle flaps, from the fat abdomen The blood supply to the abdominal fat of the obese is similar to that of the lean individual because the same number of blood vessels and capillaries are distributed to a much larger area however the adipose tissue is

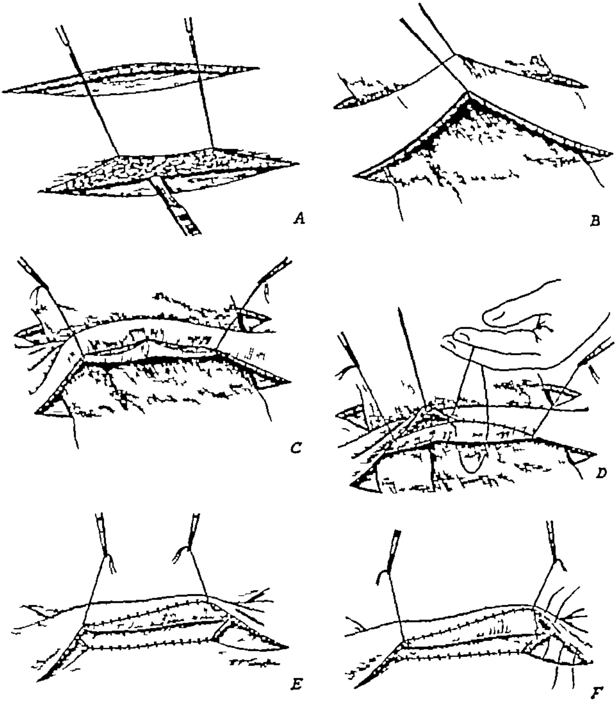

Fig. 413 The tubed pedicled flap

A Parallel incisions made and skin undermined.
B. Flap raised and gauze inserted to cover raw area
C The tubing is started by placing sutures at each end of the flap
D Tube closed with continuous suture
E The tubed portion of the flap is raised with traction sutures exposing the triangular defect remaining at each end after approximation of the edges of the donor area
F Illustrates method of closure of the triangular defect at the end of the flap

relatively less vascularized Shorter pedicles careful removal of fat to avoid strangulation and extended time intervals are indicated in the obese patient.

The first sutures should be placed approximately 2 or 3 cm from the extremity of the flap The ends of these sutures are left long and are clamped and held by the assistant who turns the pedicle over in order that the cut edges of the tube are accessible (Fig 413C) Fine interrupted sutures, or a continuous running suture are used for closure (Fig 413D) Careful suturing is an essential step in preventing the formation of a widened or hypertrophic scar which because it must be excised later diminishes the width of the flap such a scar by its longitudinal pull also tends to shorten the flap Two V-shaped defects remain at each end of the tubed pedicle, one on the undersurface of the pedicle and the other on the raw surface of the donor site (Fig 413E) This double V-shaped area may be closed by a special suture (Fig 413F) At the completion of the operation a dressing is placed in such a manner that the tubed flap remains uncovered and open to inspection (Fig 414)

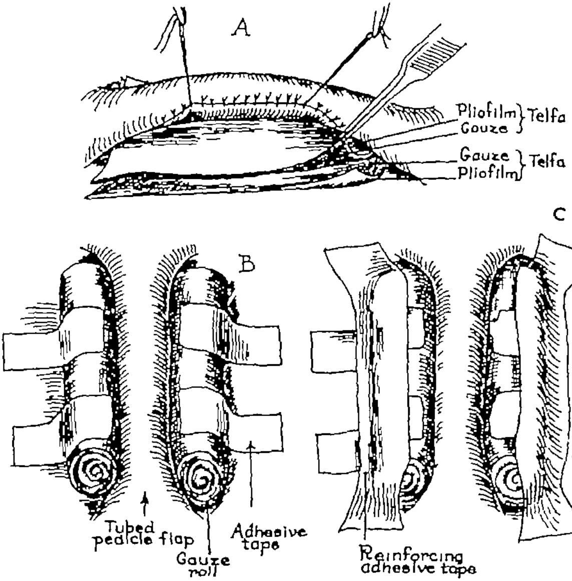

Fig 414 Dressing for tubed pedicled flap

A. At the completion of the operation a non-adherent dressing is placed over the sutured donor site B and C. Rolled gauze compresses are placed on each side of the flap maintained in position by adhesive tape. The flap remains open for inspection.

Variations in Technique

The two parallel incisions which outline a tubed pedicle flap may be staggered (Davis and Kitlowski 1936 Fig 415*A*) The advantages of this technique are two-fold greater accessibility to the triangle at the base of the pedicle permits easier placement of the sutures, and a wider base is obtained at each end of the pedicle. Closure of the triangle at the end of the closed donor site is facilitated by making two short incisions at right angles to the ends of the wound edges (Fig 415*B* Karanjian). The two advancement flaps thus created also aid in approximating the edges of the donor area along the entire length of the wound Penn (1918) advocated parallel zig zag borders for the formation of pedicled flaps in preference to straight ones (Fig 415*C*) he found it easier to close the donor area by suture with little tension. The suture lines on the tubed flap becoming irregular and thus elongated permit greater mobility when transferring the flap

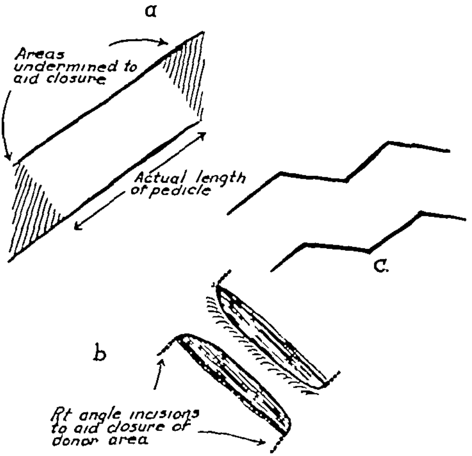

Fig 415 (A) Incisions for tubed pedicled flap may be staggered to facilitate closure of the triangles
(B) Right angle incisions aid closure of donor area
(C) Broken line incisions facilitate closure of the defect

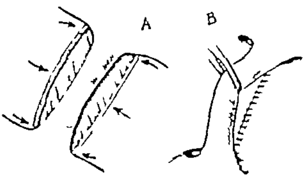

Fig 416 Closure of the donor site of a tubed pedicled flap by advancement flaps
A Outline of advancement f
B Advancement flaps mobil

Closure of the Donor Site

Wide undermining of the skin edges between the fat and the fascia at the sides

of the donor area is necessary to relieve tension and permit approximation Interrupted everting or end-on mattress sutures then complete the approximation of the wound edges. The method of closure by two advancement flaps is shown in Figure 416

Closure of the donor site of an abdominal tubed pedicle flap is facilitated by positioning the patient. Relaxation of the abdominal wall may be obtained by raising the head and foot of the operating table in order to aid the approximation of the wound edges.

In closing abdominal donor areas greater relaxation may be obtained by incising the undersurface of the undermined lateral flaps at a distance from the wound edges the relaxing incisions are made through the subcutaneous tissue to the base of the dermis.

Relaxation of the abdominal wall is achieved during the healing period by maintaining the patient in Fowler's position In young patients in whom closure is effected only with considerable tension the Fowler position should be maintained for a period of approximately seven days to prevent postoperative separation of the wound edges the erect position should be permitted only progressively during the following week.

It is usually possible to close the donor site of abdominal tubed pedicled flaps by direct approximation Small tubed pedicled flaps raised in the neck or arm leave donor areas of relatively small size which are readily closed by direct approximation

It is necessary to skin graft the donor site when sizeable tubed pedicled flaps are prepared on the chest or back. After formation of the tube, a split-thickness skin graft is spread over the donor area and fastened by a number of end-on mattress sutures these are tied, and one end of each suture is permitted to remain long A "tied in pressure dressing is then applied and retained by the suture ends. Rolled gauze is placed on each side of the tubed pedicle and a pressure dressing over the skin graft is immobilized by two wide parallel strips of adhesive on each side of the pedicle (see Fig 414) The tubed pedicled flap thus remains exposed for direct observation during the postoperative period.

The incisions made previous to raising and tubing the skin should lie parallel to natural skin folds to minimize the resultant scar The scar widens when the donor site has been closed under considerable tension but loses its redness in time, becomes flattened and in some cases, is less objectionable than a skin graft.

Elongation of a Tubed Pedicled Flap

The length of a tubed pedicled flap generally should not exceed two to two and one half times its width. A long tubed pedicle may be required when direct transfer of a tubed flap from the abdomen to the face is planned a thin narrow and elongated tubed pedicled flap may be indicated for the restoration of a missing helix border (Fig 417) Various methods may be employed in such cases (1) two or more tubed pedicles are made and the flaps are joined later by tubing the intermediary skin (Fig 417 418*A*) (2) the tubed pedicled flap may be lengthened by repeatedly tubing the skin at one end of the pedicle (Fig 418*B*) (3) a bridge of tissue is left on one side of the flap to insure an adequate blood supply (Webster 1937 Fig 418*C*) this portion being tubed at a later date and (4) an additional method is to reapply a portion of the flap into the donor site if the length of the pedicle appears excessive (Fig 419)

Detachment of the Pedicle

It is advisable to await the healing of both the tubed pedicled flap and the underlying wound before detaching the pedicle, a process which usually requires a period of four to six weeks in adults in children these intervals can be shortened to 18 to 21 days. The technique of the tubed pedicled flap should not be hurried in planning the reconstruction one should anticipate

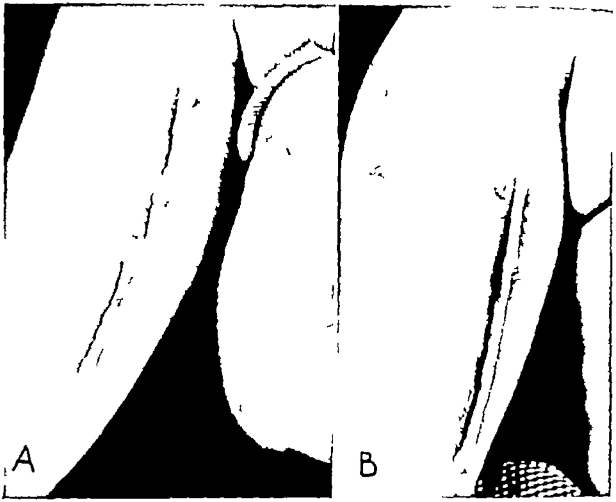

FIG. 417 Construction in stages of a long narrow tubed pedicled flap on the inner aspect of the arm. The median portion of the flap should be retained for a minimum of four weeks.

A. Appearance of the flaps prior to being joined by the technique shown in Figure 418A

B Appearance of the flap after joining the three tubes shown in A.

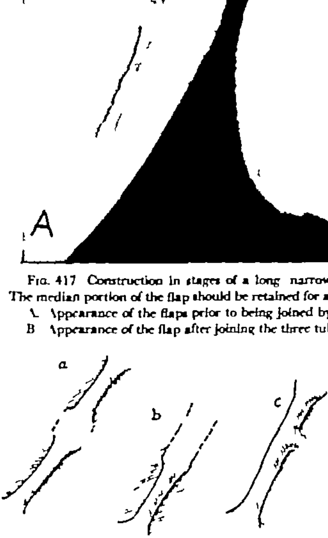

FIG 418. Methods of lengthening tubed pedicled flap

A Two flaps tubed and joined together at a later date

B Tube lengthened in stages

C. Bridge of tissue left on one side and tubed at a later date

a longer rather than a shorter period of time

In detaching one end of a tubed pedicle the incision should be made between the extremities of the parallel incisions (Fig 420*A*) the skin within this area participates in the delay of the flap It is not safe to include any of the undelayed surrounding skin with the flap, since the undelayed area may become necrosed after detachment of the pedicle A flap of skin attached to a tubed pedicle ("racquet" shaped flap) can be transferred after suitable delay has been achieved by preliminary outlining incisions and undermining (Fig 420*B*)

Prior to reimplanting the detached end of the tubed pedicled flaps, it should be opened and spread by removing a portion of the scar at the longitudinal suture line (Fig 421) this procedure increases the surface of contact between the flap and the area

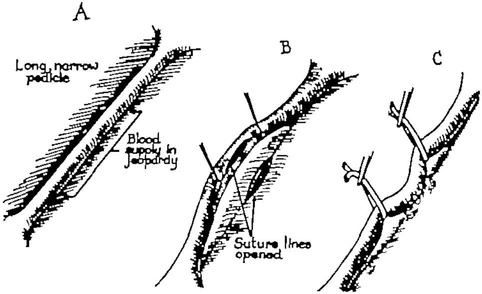

FIG 419 Technique of increasing the vascular supply when a tube is too long Sutures are removed from the mid portion of the closed donor site (B) These two raw areas are approximated by suture of the edges (C)

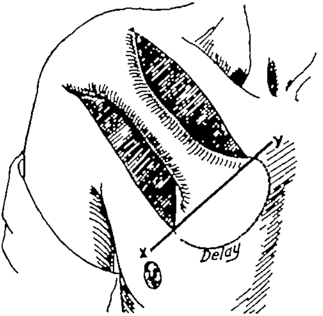

FIG. 420 The safety line X Y in detaching one end of a tubed pedicled flap. Beyond this line the flap is not delayed.

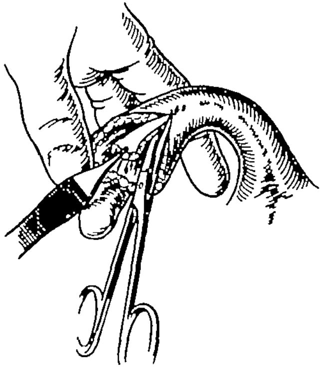

FIG 421 Central scar removed from end of tubed pedicle

of reimplantation. Sharp angles at the end of the flap should be trimmed (Fig 422) lest they undergo ischemic necrosis

Tests for the Evaluation of Circulation in Flaps

Many tests have been used to evaluate the circulation in flaps in order to hasten their transfer Lange and Boyd (1942) Dingwall and Lord (1943) and Hynes and Mac Gregor (1949) employed tests with fluorescein The principle of the fluorescein method is the observation of uniform fluorescence in a pedicle upon which a tourniquet has been placed at one end the fluorescence is observed under ultraviolet light after intravenous injection of sodium fluorescein Circulation through the non-constricted end of the pedicle is considered adequate and the flap is ready for transfer when uniform fluorescence is observed.

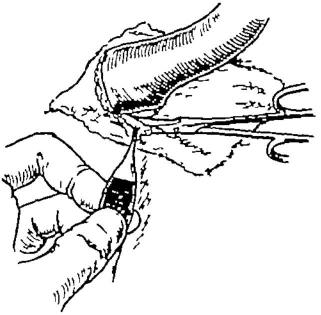

FIG 422. Sharp corners trimmed from end of tubed pedicle

The technique of Douglas and Millikan (1917) *utilizes the measurement of the blood* content of a pedicle flap by means of an oximeter The flap may be safely transferred if a rapid increase of the blood content of the flap is observed following the release of a tourniquet

The atropine absorption test (Hynes, 1918) provides a simple method of estimating the blood supply of a given tissue both qualitatively and quantitatively It is based upon the rate of absorption of atro*pine in ischemic tissue or tissue with in*adequate venous drainage which shows no absorption while highly vascular tissue with adequate venous drainage absorbs rapidly The subcutaneous injection of atropine 1/21 gr in the flap raises the pulse rate from 72 to 101 per minute in 10 minutes and 118 per minute in 20 minutes.

The histamine wheal test (Conway Stark and Joslin 1951) is based on the work of Thomas Lewis (1927) who showed that *stroking the skin initiated a triple response* The first response is a "white reaction which consists of a blanching of the skin due to the constriction of minute venules. The red reaction termed flare reaction is quantitatively different from the former for the larger arterioles are dilated. This phenomenon is due to the action of a histamine-like substance upon the sympathetic nerve endings and is dependent upon an intact nerve supply The histamine-like substance also produces a modification in the vessel wall which results in a transudation of plasma and the production of a local wheal Such a wheal does not form unless *an adequate blood flow is present Its for*mation is independent of innervation. The histamine wheal test is done by scarifying a small area of the skin of the pedicle with a needle. A drop of acid phosphate salt of histamine (solution 1 1000) is applied and the number of minutes required for the development of the cutaneous wheal is compared with a control area as an index of circulatory efficiency

Testing the efficiency of the circulation *in flaps is occasionally a useful procedure in* a very long tubed pedicled flap for one may hesitate to transfer such a long flap before verifying the adequacy of the circulation or when transferring a flap to the face which is carried on the wrist Every effort should be made to shorten the period of discomfort for the patient, and one of the tests described above may be employed. We have found little use for such tests in most flap transfers. The shortening of the *transfer time by 7 to 14 days is not of any* particular advantage when tubed pedicled flaps are required. One may avoid the necessity of checking the efficiency of the circulation by constructing flaps of adequate proportions and not attempt to design tubed flaps that are too long in relation to their width If a wide surface of skin is desired, a different type of flap may be preferable One can also perform an additional delay at the end of the tubed pedicled flap to *be detached in doubtful cases.* The danger of losing the flap and the need for a delaying surgical procedure disappear if the transfer of the tubed flap is postponed for a sufficient time *interval* This permits the establishment and consolidation of a de

finitive arterial, venous and lymphatic vasculature in the flap and also the softening of the intratubular fibrous tissue We have repeatedly noted that the results are better when long time intervals are allowed between stages of construction of tubed pedicled flaps

In certain types of transfer where the position is particularly uncomfortable for the patient, such as the transfer of a flap which is carried to the face on the upper extremity it is possible to section the pedicle of the flap in children as early as the tenth or twelfth day Clinical judgment is necessary in such cases the time to sever the pedicled flap being based upon the degree of healing of the flap to the bed, and the area to which the flap is applied. In the face, where the blood supply is good revascularization is generally rapid and early severance of the pedicle can be accomplished without losing the flap

Constriction of the Tubed Pedicled Flap before Separation

A technique suggested for the promotion of adequate circulation from one end prior to separation is to constrict the other end by means of an elastic band (Fig 423) which is placed around the end of the tubed pedicled flap and is maintained by means of a hemostat. Constriction is continued for a period of one hour then re-

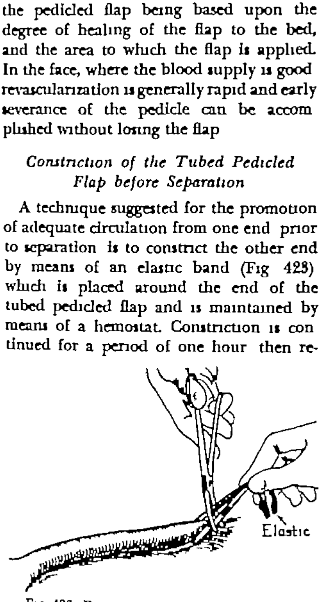

Fig 423 Demonstrating intermittent compression by elastic tourniquet prior to detachment of a tubed pedicled flap

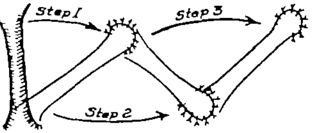

Fig 424 The "waltzing" method of migrating a tubed flap

leased and on the second day is applied for a period of two hours the time being gradually increased for a period of 10 or 12 hours This method serves to evaluate the adequacy of circulation in long tubes if there is doubt about the survival of the distal end of the flap the flap becomes blue if it is not well vascularized Constriction of one end of the flap however is a questionable procedure from the point of view of enhancing the circulation in the flap

Delay of the Distal End of A Tubed Pedicled Flap

A delay operation is necessary before transfer if the vitality of the flap is in doubt, or when planning a racquet" or pancake extension" type of flap with a section of skin left attached to the distal end of the tubed pedicled flap (Fig 420) Surgical delay is achieved by partial incision and detachment of the end of the flap When preparing an extension to a tubed pedicle the area may be circumscribed by numerous interrupted incisions in a first stage in a later stage the addition to the flap is raised then sutured back in position the flap is transferred in a third stage. Delay should be done at least 15 to 21 days before each subsequent stage. Usually however one should not fear the detachment of a pedicle when the proportions of the flap are adequate preliminary delay of one end of the flap is not required.

Transfer of a Tubed Pedicled Flap

Direct transfer is possible when the pedicle is of sufficient length to reach the face

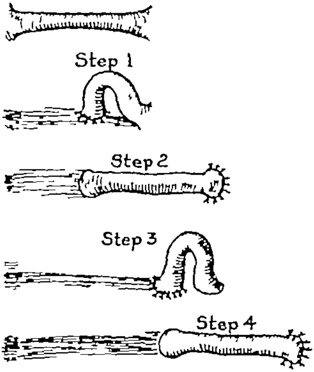

Fig 425 The "caterpillar" method of migrating a tubed flap

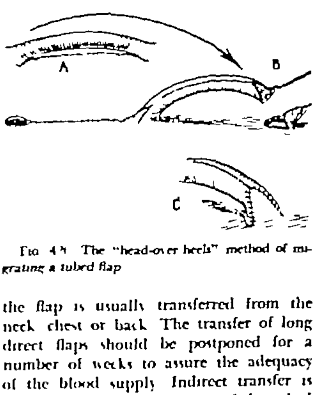

Fig 426 The "head-over heels" method of migrating a tubed flap

the flap is usually transferred from the neck chest or back The transfer of long direct flaps should be postponed for a number of weeks to assure the adequacy of the blood supply Indirect transfer is required when the donor site of the tubed flap is too far from the face to permit direct transfer Three methods of indirect transfer of a distant flap follow

1 *Waltzing the flap* This expression is used to designate a procedure which consists of detaching one end of a tubed pedicled flap and inserting it into an area closer to the defect (Fig 424) the procedure is then repeated at a later date by *detaching* the other end of the tube.

2 The caterpillar flap. One end of a tubed pedicled flap, (A) is detached and reattached at a point close to the other end (B) (Fig 425) After three or four weeks delay (B) is advanced and reattached closer to the defect

3 The "head over heels" technique. This technique thus aptly designated by Gillies, consists of detaching one end of a tubed *flap and then raising and implanting it* beneath a triangular-shaped flap (Fig 426).

These procedures of indirect transfer are hazardous and should be resorted to only in exceptional circumstances. Each detachment of the pedicle is an operative risk and increases scar tissue diminishing the vitality of the flap.

4 The tubed flap carried on the forearm A tubed pedicle can be migrated to the recipient area by attaching one end of the flap *to the upper extremity which serves to* carry the flap to the face.

TECHNIQUE. One end of the tubed pedicle is detached opened the central scar is removed (Fig 421) and the sharp corners are trimmed (Fig 422) The raw area thus produced is pressed against the portion of the upper extremity selected to serve as the carrying medium or on a part of the body closer to the face if the flap is to be migrated in steps. Application of slight pressure leaves a blood stained pattern (Fig 427*A*) which is then outlined in ink A trapdoor flap made along this outline is raised from the fascia its general shape is roughly triangular to embrace the triangular raw area of the detached end of the tubed pedicle (*Fig 427B*) The skin edges *of the* two raw areas and of the trap-door flap are *approximated with fine sutures (Fig 427C–F)* Healing occurs and blood vessels from the new host bed grow into the tubed pedicle (Fig 428) The distal end of the pedicle is then detached and sutured into the defect

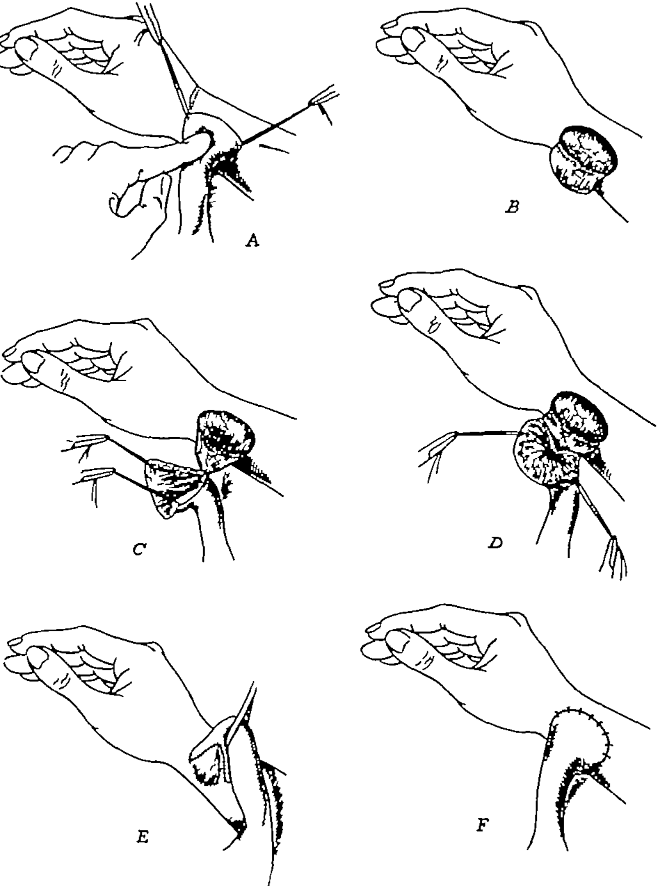

FIG. 427 Technique of implantation of the end of a tubed pedicled flap into the wrist

A. The raw area at the end of the pedicle is pressed against the wrist thus making a blood stain.

B. Trap-door flap raised.

C. The end of the trap-door flap is sutured to the edge of the raw area at the end of the tubed pedicled flap

D Suture of the trap-door flap to the tubed pedicle is completed.

E. Illustrates the junction of the trap-door flap with the tubed pedicled flap.

F Illustrates suture of the end of the tubed pedicle into the defect of the wrist.

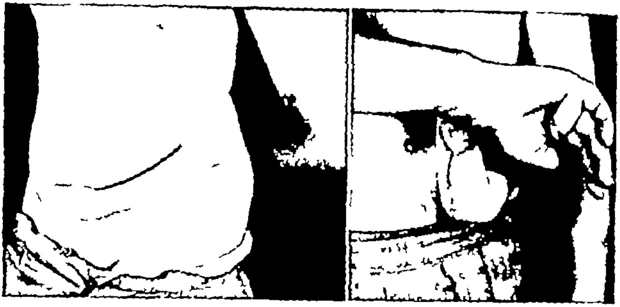

FIG. 428

(*Left*) Typical abdominal tubed pedicled flap.
(*Right*) Shows attachment of tubed pedicle to the wrist.

The point of insertion of the tubed pedicle flap into the upper extremity varies. The hand, and more frequently the wrist and forearm, have been employed as carriers. The selection of the radial or ulnar side of the wrist depends upon the position that the upper extremity assumes when the flap is transferred to the face or neck. The position employed most frequently is that of the hand upon the opposite shoulder, the tubed pedicle being implanted on the radial border of the forearm or wrist (Fig. 429).

When transferring small tubed pedicled flaps, the trap-door flap may be inserted into the side of the tube after the suture line has been opened (Fig. 430). This technique preserves the length of the flap.

A period of three to four weeks should elapse between each step of the transfer. The distal end of the pedicle is detached at the donor site and sutured into the defect after the tube is freed of scar tissue and excess fat.

Immobilization of the Upper Extremity in Flap Transfers to the Face

A flap carried on the upper extremity for transfer to the face is always a tedious procedure for the patient. Whenever possible, therefore, the position of the arm should be such that the hand rests on the shoulder (Fig. 429). This position, with the flap extending upward, favors the venous return from the flap to the extremity.

When transferring a flap from the abdomen to the face by way of the forearm or wrist, the flap should be raised on the side opposite the facial defect and carried on the extremity opposite the side of the defect. For defects on the side of the face and cheek, the arm carrying the flap is placed along the base of the neck, the hand resting on the shoulder (Fig. 429C). For transfers of flaps to the scalp, forehead or in nasal reconstruction, the flap may be attached to the radial aspect of the forearm, the extremity is placed above the head and the forearm is rotated in such a way that the volar surface faces forward, the "salute" position advocated by Kilner (1937) (see Fig. 771, Chapter 22). Another procedure is to attach the flap on the ulnar aspect of the forearm, placing the extremity above the head in such a way that the volar aspect of the forearm rests on top of the head (Fig. 431).

We have employed adhesive tape for

FIG 429 Indirect transfer of a flap to the face
A. Oblique abdominal tubed pedicled flap
B Attachment of the posterior end of the flap to the dorsal and radial aspect of the wrist.
C. Position of transfer of the flap carried to the face on the wrist.
D Aspect of the flap transferred to replace an area of radiation burn scar

simple immobilization in many such transfers. A large sheet of adhesive tape about 1 meter in length and 40 cm. in width is wrapped around the patient's body supporting the elbow of the flap-carrying extremity and providing fixation of the arm against the chest (Fig 432) Less favorable positions of the upper extremity in flap

transfers to the face require more complicated means of immobilization. Special harnesses made of leather were employed by Tagliacozzi (1597) Malgaigne (1874) used a jacket made of cloth (Fig 433) The cloth jacket was prepared in advance but left open on one side to simplify its placement on the patient and then sewed together to assure fixation at the time of transfer

When a flap is to be transferred to the upper portion of the face and to the scalp the upper extremity is placed above the head This is a difficult position for the patient to maintain and more adequate immobilization must be provided. A plaster cast of the "Minerva" type can be employed enclosing the head and the trunk (Fig 431D) the apparatus, however is heavy bulky and uncomfortable Darcissac (1919), during the first World War developed light and practical plaster head caps to which he placed attachments, permitting the immobilization of the extremity to the head cap with the aid of a plaster cast applied in a circular fashion around the upper extremity

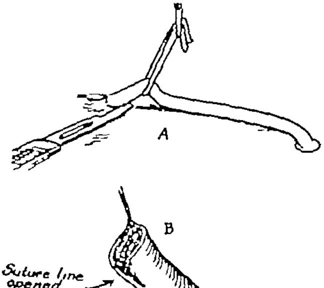

Fig 430 Transfer of a small tubed pedicled flap
A. Detachment of the tubed flap
B The seam of the tube is opened
C A triangular flap is inserted into the opened seam in the tube

Types of Tubed Pedicled Flaps Used for Facial and Cervical Repair

When skin tubes are removed from various areas of the body for transfer to the face the color and texture match usually decrease in quality as the distance between the donor area and the face is increased.

Cervical tubed flaps should be made parallel to the skin folds of the neck. The donor site is placed below the collarline in male patients in female patients the donor site may be at the base of the neck within the lowermost crease line for the slightly visible resultant scar may be hidden by a necklace Long tubed pedicled flaps crossing the mid line should be prepared in stages (Fig 431) Vertical tubed flaps should be avoided because of resulting hypertrophic scarring Small tubed pedicled flaps may be prepared in female patients in an area adjacent to the hairline the resultant scar is concealed by the patient's hair

Tubed pedicled flaps may also be prepared in the acromiothoracic area (Fig 435A) and from the scapular area these can be transferred directly to the face and neck. The skin of the back despite a considerably thicker dermal layer has proved satisfactory for face and neck repairs.

Abdominal tubed pedicled flaps are used when a large surface of skin is required for massive defects (Fig 429) Abdominal tubes should be made parallel to the skin folds of the abdomen usually extending from a point lateral to the umbilicus and upward laterally and posteriorly in the area between the iliac crest and the lower costal margin

Brachial tubed pedicled flaps can be em

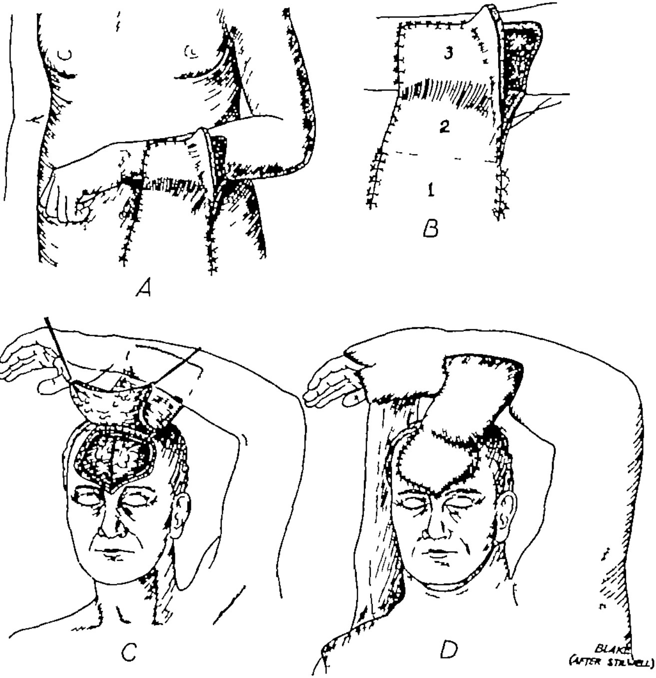

Fig 431 The closed carried flap

A. Attachment of abdominal flap to the forearm. Note the forearm hinge-flap turned down to line the abdominal flap

B. Details of the junction of forearm and abdominal flaps Portion 1 of the flap is attached to the abdomen. Portion 2 is lined by the forearm flap Portion 3 is applied to the forearm.

C. After the flap has been severed from the abdomen, it is carried on the forearm to the frontal region Note the distal end of the forearm hinge-flap sutured to the upper edge of the defect.

D The closed carried flap in position. The upper extremity is maintained immobilized by a plaster cast. (From J M. Converse, R. M. Campbell, and W L. Watson, Ann Surg 133:95 1955)

ployed as small-calibered tubes and are prepared on the inner aspect of the arm for transfer to the helix border of a reconstructed ear (Fig 417)

Modes of Utilization of Tubed Pedicled Flaps

Tubed pedicled flaps can be utilized in various ways (1) one extremity of the flap is

transfers to the face require more complicated means of immobilization. Special harnesses made of leather were employed by Tagliocozzi (1597) Malgaigne (1874) used a jacket made of cloth (Fig 433) The cloth jacket was prepared in advance but left open on one side to simplify its placement on the patient, and then sewed together to assure fixation at the time of transfer

When a flap is to be transferred to the upper portion of the face and to the scalp the upper extremity is placed above the head This is a difficult position for the patient to maintain and more adequate immobilization must be provided. A plaster cast of the "Minerva" type can be employed, enclosing the head and the trunk (Fig 431D) the apparatus, however is heavy

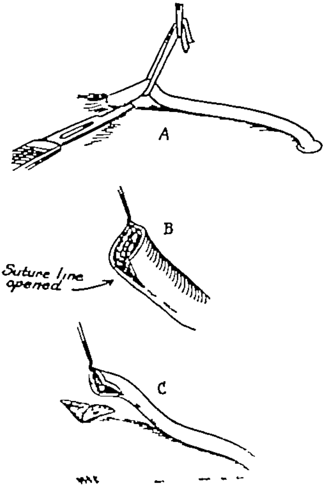

Fig 430 Transfer of a small tubed [illegible]
A Detachment of the tubed flap
B. The seam of the tube is opened
C. A triangular flap is inserted int[o] t[he] seam in the tube

bulky and uncomfortable. Darcissac (1919) during the first World War developed ligh[t] and practical plaster head caps to which h[e] placed attachments, permitting the immobi[li]zation of the extremity to the head ca[p] with the aid of a plaster cast applied i[n] a circular fashion around the upper ex[tremity]

Types of Tubed Pedicled Flaps Used fo[r] Facial and Cervical Repair

When skin tubes are removed from vari[ous] areas of the body for transfer to th[e] face the color and texture match usuall[y] decrease in quality as the distance betwee[n] the donor area and the face is increased.

Cervical tubed flaps should be made par[allel] to the skin folds of the neck. Th[e] donor site is placed below the collarline i[n] male patients in female patients, the dono[r] site may be at the base of the neck withi[n] the lowermost crease line for the slightl[y] visible resultant scar may be hidden by [a] necklace Long tubed pedicled flaps crossin[g] the mid line should be prepared in stage[s] (Fig 434) Vertical tubed flaps should b[e] avoided because of resulting hypertrophi[c] scarring Small tubed pedicled flaps may b[e] prepared in female patients in an are[a] adjacent to the hairline the resultant sca[r] is concealed by the patient's hair

Tubed pedicled flaps may also be pre[pared] in the acromiothoracic area (Fig 435A) and from the scapular area thes[e] can be transferred directly to the face an[d] neck. The skin of the back despite a con[siderably] thicker dermal layer has prove[n] for face and neck

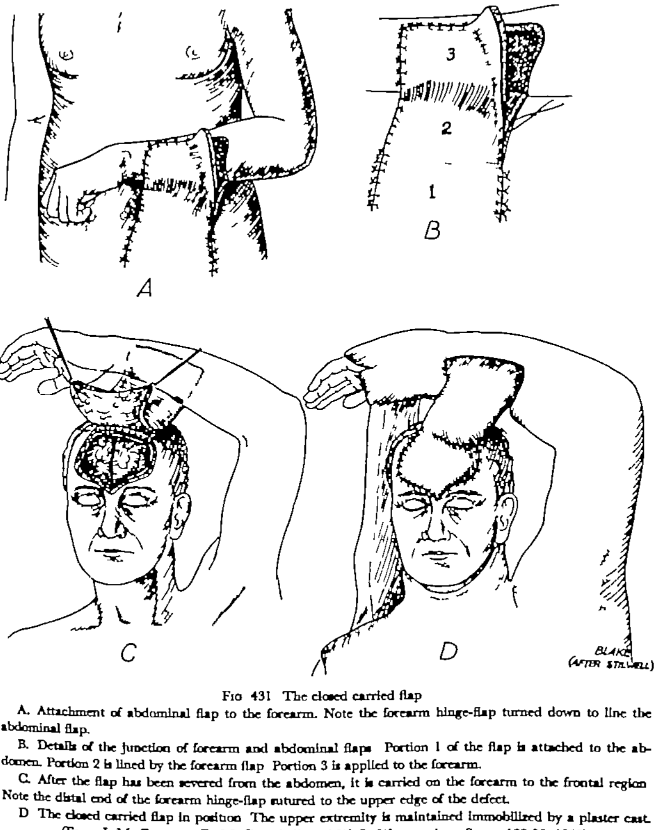

FIG 431 The closed carried flap

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D The closed carried flap in position The upper extremity is maintained immobilized by a plaster cast.

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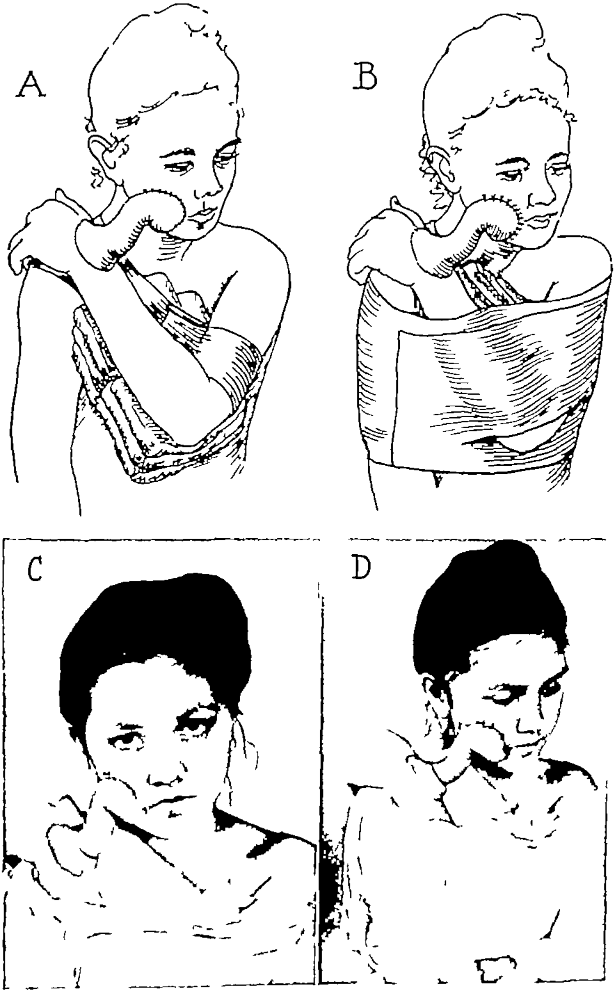
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B
C
D

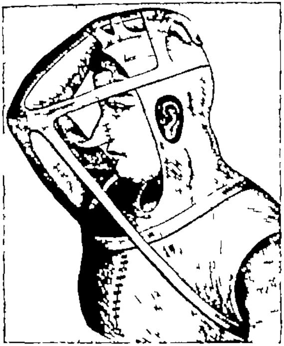


Fig 433 Cloth jacket employed for fixation of the upper extremity in flap transfer from the arm (Malgaigne, 1861)

Fig 434 Example of a horizontal cervical tubed pedicled flap crossing the mid-line.

used to cover the entire defect the remainder serves as the carrying portion (2) after the flap has healed to the defect, the carrying portion is detached opened, and used to cover the remainder of the defect, (3) both extremities are implanted on each side of the defect, the tube bridging the defect, and in a later stage the intermediary portion of the flap is opened and applied to the defect (Fig 436) It is often necessary to sever one of the pedicle attachments, preferably the second attachment which was implanted at the previous operation open the intermediary portion and fully spread and advance the flap to smooth the kink which usually forms at the junction of the remaining tubed portion with the pedicle attachment (Fig 436C D) The kink at the junction with the first attachment is smoothed at a later operation

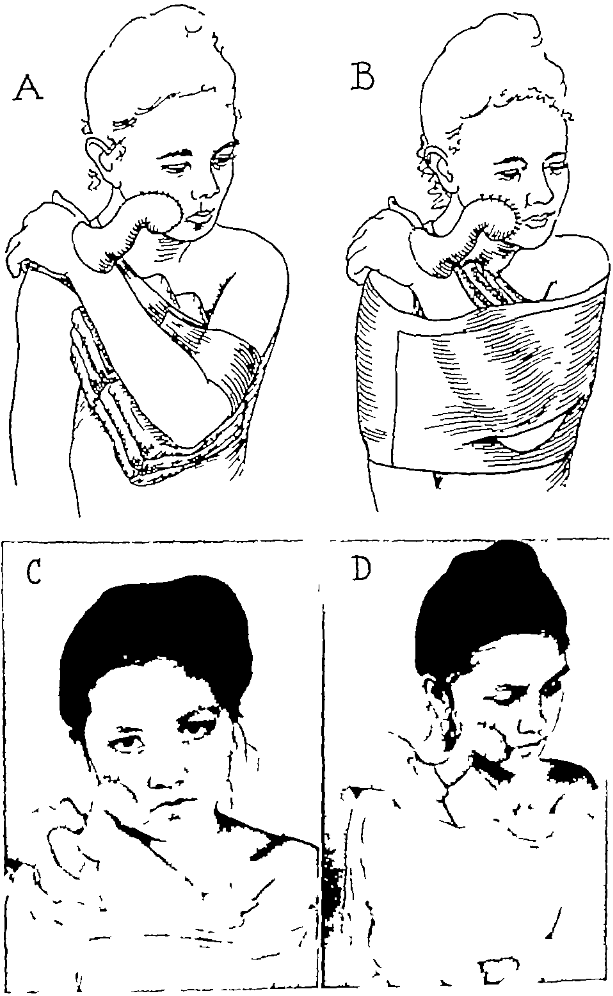
Other Varieties of Pedicled Flaps

The Lined Flap

When a flap is to be lined on its under surface to restore the full thickness tissue of the nose or cheek the lining may be provided by a free graft or by a flap

Free grafts may be split thickness or full thickness skin grafts Thicker grafts are preferable in order to minimize subsequent contraction The graft is usually sutured in position under the flap in a preliminary step as illustrated in Figures 437 438 or it can be applied after transfer A free skin graft may also be employed not as a

Fig 432. Fixation of the upper extremity in indirect flap transfer
A. Gauze pads placed between the upper extremity and the chest.
B Wide strips of adhesive tape applied in a circular fashion to maintain the fixation of the upper extremity
C and D Appearance of the patient during flap transfer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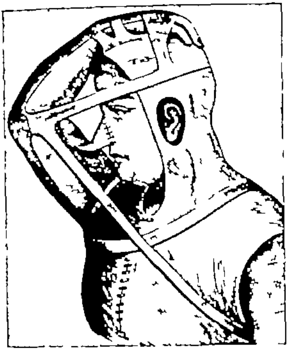

Fig 433 Cloth jacket employed for fixation of the upper extremity in flap transfer from the arm (Malgaigne, 1861)

Fig 434 Example of a horizontal cervical tubed pedicled flap crossing the mid-line.

used to cover the entire defect, the remainder serves as the carrying portion (2) after the flap has healed to the defect, the carrying portion is detached opened and used to cover the remainder of the defect (3) both extremities are implanted on each side of the defect, the tube bridging the defect and in a later stage, the intermediary portion of the flap is opened and applied to the defect (Fig 436) It is often necessary to sever one of the pedicle attachments, preferably the second attachment which was implanted at the previous operation open the intermediary portion and fully spread and advance the flap to smooth the kink which usually forms at the junction of the remaining tubed portion with the pedicle attachment (Fig 436*C D*) The kink at the junction with the first attachment is smoothed at a later operation.

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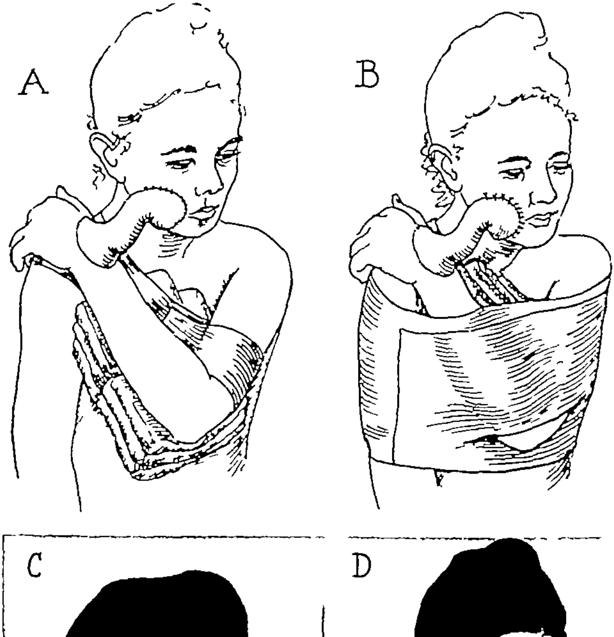
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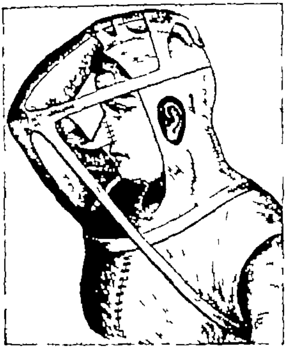

FIG 433. Cloth jacket employed for fixation of the upper extremity in flap transfer from the arm (Malgaigne, 1861)

FIG 434 Example of a horizontal cervical tubed pedicled flap crossing the mid-line.

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C and D Appearance of the patient during flap transfer

Fig 435 Acromiothoracic tubed pedicled flap. Note the position of the upper extremity to approximate the acromial base of the pedicle to the face (after Gillies, 1935)

lining but as the covering of the defect the pedicled flap supplies the lining (see Fig 765 Chapter 22) A full thickness retroauricular or supraclavicular skin graft may be placed to cover the raw surface of the flap which lines the defect

Composite grafts of mucoperichondrium and septal cartilage (chondromucosal grafts) or of skin and auricular cartilage (chondrocutaneous grafts) have been employed to line forehead flaps for full thickness defects of the nose (see Fig 780 Chapter 22)

A pedicled flap may also be lined by folding its distal portion on itself (Fig 459) or by means of another flap (Fig 431).

The Closed Carried Flap

The closed carried flap (Converse 1918) also known as the jump flap (Cannon *et al* 1917) is a direct abdominal flap attached to the patient's forearm which is closed by a hinge flap from the forearm (Fig 431). It is a relatively rapid and safe method which permits the shifting of a wide flap to the face. Raw areas, open to infection, are avoided because the flap is closed The closed carried flap has the advantages of the tubed pedicled flap with the added possibility of more rapid transfer and better vascularization than the tubed pedicled flap because of the wide base

The closed carried flap is usually raised from the abdomen attached to the forearm and transferred to the defect. A cloth pattern of the future defect is made the optimum position of transfer is determined and the forearm is placed in proximity to

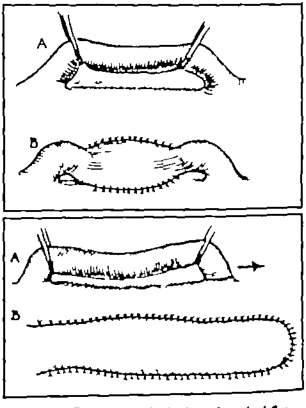

Fig 4[illegible] Eliminating the kink in the tubed flap

A A tubed flap is attached on each side bridging over the defect the median portion of the flap remains tubed

B The median portion of the tube is opened and inverted Note the kink on each side requiring secondary raising the spreading

A and B Alternate technique the kink is eliminated if one end of the flap is detached and the flap is opened and spread

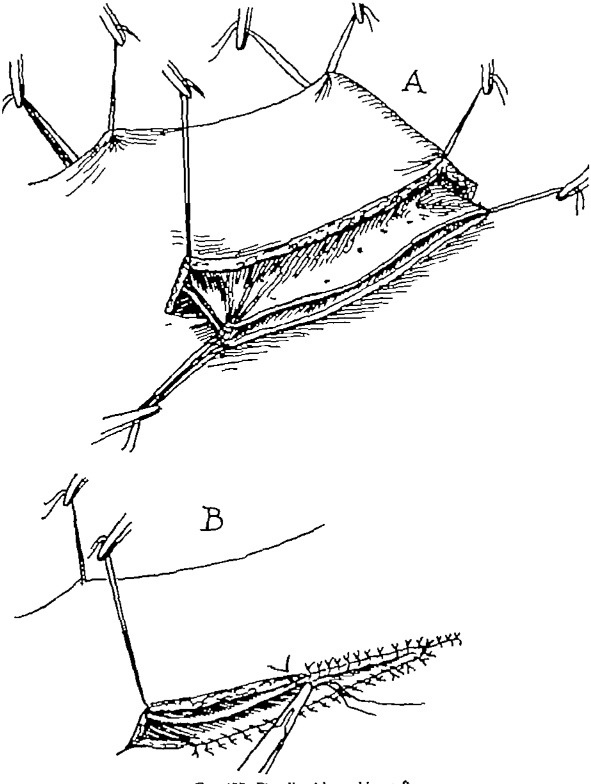

FIG 437 Flap lined by a skin graft

A. Split thickness skin graft folded on itself is placed under flap

B Suturing of the edge of the skin graft to the edge of the flap One layer of skin graft serves to line the flap while the other covers the donor site of the flap.

the defect. A pattern is cut to shape and is fitted to the defect as though the operation of flap transfer had already been performed. The pattern is applied to the forearm which is then displaced downward over the abdomen and spread over the abdominal donor area an outline of the future flap is then made.

To insure the survival of the flap, the proportions should be such that the length

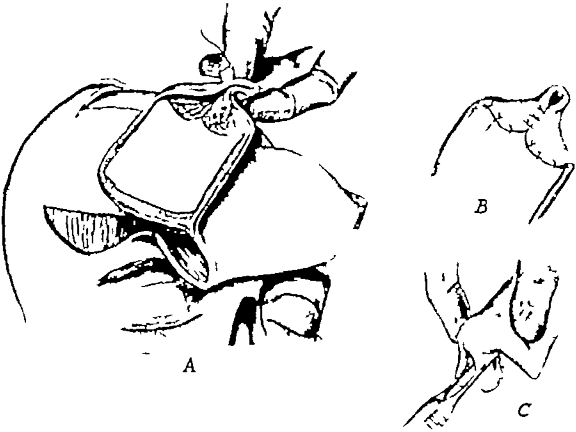

Fig 438
A. Appearance of lined forehead flap ready for transfer for nasal reconstruction.
B, C. Method of folding the end of the flap forming the columella and tip

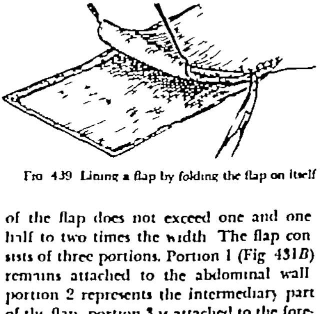

Fig 439 Lining a flap by folding the flap on itself

of the flap does not exceed one and one half to two times the width The flap consists of three portions. Portion 1 (Fig 431*B*) remains attached to the abdominal wall portion 2 represents the intermediary part of the flap portion 3 is attached to the forearm The flap from the forearm is reflected back as a hinge flap which covers the raw surface of portion 2.

FIRST STAGE RAISING THE FLAPS. The flaps previously outlined are raised by sharp dissection of the subcutaneous fat layer from the underlying deep fascia The corners of the flaps should be rounded careful hemostasis fine sutures and delicate handling are requisites for success. The secondary defect produced by raising the abdominal flap is skin grafted.

SECOND STAGE TRANSFER. Transfer is postponed for three to four weeks or until healing of the edges of the flap is complete

The distal portion of the forearm flap is sutured to the lower edge of the defect after being dissected from portion 2 of the flap for a distance of 3 to 5 cm (Fig 431*C*). Portion 1 and a part of portion 2 of the main flap are placed over the defect and carefully sutured to its edges (Fig 431*D*).

THIRD STAGE SEVERANCE OF THE FOREARM ATTACHMENT OF THE FLAP The attachment to the forearm is severed three weeks after

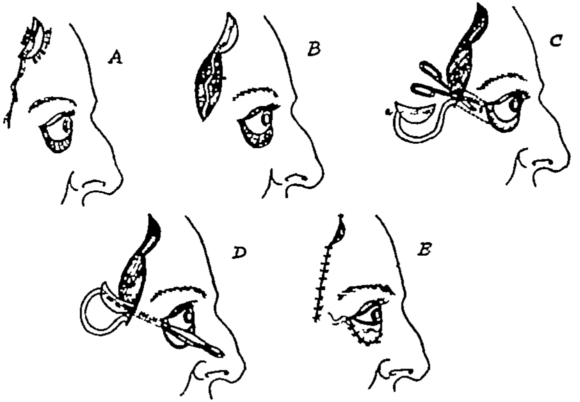

FIG 440 Island artery flap (reproduced from Monks, 1898)
A. Flap of skin outlined in the right temporal area
B The superficial temporal vessels have been dissected.
C. A subcutaneous tunnel to the right lower eyelid is made.
D The island artery flap is ready to be pulled through the tunnel
E. Island artery flap in position

the transfer of the flap A longer period may be allowed before separation of the flap when vascularization of the recipient area is deficient. The forearm flap is replaced in its original position and the edges of the flap are sutured to the edges of the defect.

Reinforced Flaps

Flaps are provided with rigidity if autogenous cartilage is implanted under them before transfer Composite grafts from the septum or the auricle may be employed. Examples of reinforced flaps are those utilized for reconstructive surgery of the nose and ear (see Chapters 22 and 28)

Artery Island Flap

A variation of the distant direct flap is the artery island flap The principle employed is the utilization of blood vessels as pedicles (Monks, 1898 Esser 1917) Esser named this type of flap the biological flap An island of skin is incised and detached except for the vascular pedicle which is dissected from the surrounding tissue without injury to the vessels. The skin with its vascular pedicle is then introduced into the recipient area through a subcutaneous tunnel (Fig 440)

Island Flap (Kazanjian)

An island of skin is prepared by a circumferential incision but is not separated from the subjacent tissues. The island flap is shifted to a new position Its use is limited to areas where the skin is loosely bound to the underlying tissues, as in the supraorbital area or the eyelids (Fig 441)

Postoperative Removal of Excess Fat after Transfer of Flaps

A transferred pedicled flap may contain an excessive amount of subcutaneous fat

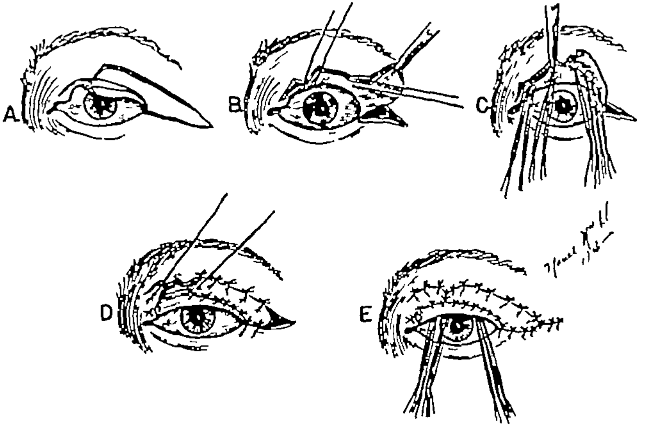

Fig. 441 The island flap

A. Outline of flap which is incised around its entire periphery but left attached to the subcutaneous tissue for repair of a defect of the upper eyelid

B. Suture of the conjunctiva is started.

C, D Suture of the conjunctiva is completed. Note the advancement of the island flap.

E. The flap has been advanced and the secondary defect lateral to the canthus closed by direct approximation.

The removal of this fat is referred to as "de fatting" one half of the total surface area of the flap is raised from its bed and the fat is transected at a level which represents the desired thickness of the flap the remaining fat in the recipient bed is then excised The flap is resutured into its bed after careful hemostasis, and its edges are sutured to the edges of the wound.

Peer (1957) noted that the amount of fat under a transplanted pedicled flap increases when the patient gains weight. The removal of excess fat should be postponed therefore until normal weight has been regained

Planning the Skin Flap

Flap transfer from the upper extremity to the face entails discomfort for the patient a donor area close to the face should therefore be selected whenever possible Although rapid repair is desirable the quality of the final repair should not be sacrificed for speed of execution Simple procedures often produce better results with far less delay and labor than more elaborate ones.

The repair of the donor area is accomplished by direct approximation local flaps or skin grafting The design of the flap is dependent upon the feasibility of repairing the secondary defect by one of these methods. A good result is obtained by the judicious removal of tissue from a region in which loss of tissue is less important than is the repair of the defect on the face In such "barters" of tissue the age sex profession of the patient length of hospitalization required for reconstruction and psychological aspects all merit careful consideration

The neck and upper part of the chest and back as donor areas are usually contraindicated in female patients because of added scarring in these areas. A secondary deformity below the collar line is permissible in male patients. Forehead flaps are generally less objectionable in females because a change in coiffure can conceal the defect. It is important to restore the continuity of the hair-bearing area of the face in males to avoid a hairless "patch" this often necessitates the use of flaps from the neck.

Local flaps are always preferable because of their color texture and thickness, and repair is rapid and simple.

When the local blood supply is disturbed by the presence of scar tissue considerable caution should be exercised in designing the flap lest necrosis ensue The vitality of flaps is greater in the young than in the elderly patient. A flap of adequate dimensions should be designed the angle at which the flap is raised and applied to the defect must be carefully selected to avoid tension after the flap has been sutured into its recipient bed.

Flap transfer procedures should be simplified in elderly patients, for the blood supply is limited, it is also difficult for patients in the older age group to withstand uncomfortable positions of transfer

Although the co-operation of children is often difficult to obtain they are capable of withstanding acrobatic positions of distant flap transfer with equanimity

Complications in Pedicled Flaps

Insufficient vascular supply due to inadequate proportions, kinking and twisting of the pedicle of the flap and excessive tension or hematoma which serve to obstruct the circulation all result in failure of the blood supply and necrosis of a portion of the flap or *even the entire flap*

Color changes are noted in a flap after it is raised or its pedicle is divided. Blue flaps are thought to be the result of inadequate venous drainage but both the so-called blue flap and the white flap are probably the result of arterial insufficiency

A flap appears white because of low blood pressure arterial blood entering the flap fails to reach all parts of the flap through the dilated vessels.

A blue flap is also due to the fact that the pressure of the entering blood, which is sufficient to push the blood to the end of the flap is inadequate to propel it out again Blood stagnates in the dilated vessels and danger of intravascular clotting follows

The vascular behavior of pedicled flaps is understood better if one realizes that their blood vessels are partly or completely denervated (Hynes 1950) Vessels are divided when the skin and subcutaneous tissues are incised these vessels are supplied with sympathetic nerve fibers from adjacent sensory and mixed nerves traversing the vessel walls to supply the vascular tree below Sweat tests have shown that the skin of a pedicled flap does not sweat and therefore can be considered as having undergone sympathectomy The denervated vessels dilate and are converted from actively contractile vessels to toneless, dilated passages which do not respond to changes of posture temperature or trauma. The loss of peripheral resistance in a denervated vascular tree causes a fall of the blood pressure in the affected vessels. Blood will pass through small communicating arterioles and capillaries from adjacent healthy vessels where the blood pressure is high into the denervated vessels where the pressure is low The blood entering the wide, toneless, denervated vessels is forced through them by the pressure of blood in the feeding vessels, as there is no peripheral resistance.

The color of skin depends on the caliber and blood content of the surface capillaries. The skin is red if the capillaries are dilated and blood flows through them freely from dilated arterioles The skin is blue when the capillaries are relaxed and the blood flow is sluggish. The skin appears pale when the capillaries are empty The

condition of the underlying arterioles and capillaries can thus be evaluated by studying the color of a flap after it has been raised and in the immediate postoperative period.

The presence of non-contractile vessels in a flap must be considered in posturing a patient after the flap has been transferred from one area to another. The flap becomes deep blue pink in color and loses blood when the cut end which should be elevated is placed in a dependent position. The survival of the flap is uncertain if one is not mindful of this precaution. A hematoma may form at the junction of the cut end of the flap and the recipient site because of the oozing of blood.

Means to relieve congestion in a blue flap have long been sought. Blandin (1836), Dieffenbach (1833) and Lisfranc (as quoted by Pierre, 1851) used leeches to relieve the congestion. When circulatory deficiency develops in a transplanted skin flap, efforts should be made to release mechanical obstruction to the flow of blood. Hot or cold applications over the flap are of little avail. Application of mild pressure over the flap to encourage venous return and immobilization is of assistance. Elevation can be used in such a way that the pedicle of the flap is placed in a dependent position permitting the blood to flow from the flap. Postural assistance to venous flow through the pedicle of the flap is the most effective measure.

When a hematoma forms, particularly in a tubed pedicle where it obstructs the circulation, adequate treatment consists of returning the patient to the operating room where the sutures are removed under anesthesia if necessary, the flap is opened, the hematoma is evacuated, and the bleeding vessels are clamped and tied. The removal of sutures in the area of the hematoma permits its evacuation from the interior of the tubed pedicled flap and the return of normal blood flow. Constriction is a frequent cause of interference of the blood flow in a tubed pedicled flap due to inade[quate] removal of fat prior to the tubing [of the] flap; the strangulation of adipose [tissue] within the flap causes internal pr[essure] against the vessels of the flap. Remo[val of] sutures may relieve the constrictio[n;] placement of the flap into its donor si[te may] be the only means of rescuing the f[lap.]

When the red or blue color of the fl[ap in]dicates circulatory embarrassment, on[e can] make an approximate estimate of the [prob]ability of recovery of the flap by the f[ollow]ing practical test: when digital pr[essure] against the flap causes it to become blan[ched] and release of the pressure results in a [rapid] return of the reddish or bluish colo[r, sur]vival of the flap may be anticipated. [If the] flap does not blanch when pressure [is ap]plied but retains its blue color, or if t[he re]turn of color is sluggish, the chances fo[r sur]vival are slim. When a bluish col[or is] present during the first hours after tra[nsfer] and digital pressure shows a rapid retu[rn of] color, the flap will probably recover. [Color] changes appearing twenty four or forty [eight] hours after transfer are a danger signa[l that] circulation is embarrassed because of [kink]ing or hematoma, and measures shou[ld be] taken to relieve the obstruction. Detach[ment] of the flap and replacement into the [donor] site may be the only way to save the fla[p for] future use if the circulatory deficien[cy is] due to kinking of the pedicle.

When necrosis of a portion of the [flap] occurs, the devitalized area is evident w[ithin] twenty four hours; it assumes a dark [blue] color, and after a few days a line of dem[arca]tion forms; later the necrotic tissue slo[ughs] away. The loss of even a small portion [of a] skin flap may interfere with the succ[ess of] a reconstructive procedure.

One should not dally until infection [and] suppuration are established and ne[crosis] occurs. As soon as the line of demarc[ation] appears, the pedicle should be sectione[d and] the necrotic tissue removed. In this ma[nner] the remainder of the flap may be salv[aged] for future use.

18

GRAFTS OF SKIN AND MUCOSA

A free graft of skin or mucosa is a transplant which is completely severed from its connections to the surrounding skin and the subcutaneous tissue. The skin graft consists of epidermis and dermis, the dermal layer comprising either the entire thickness, or only a portion of, the dermis (Fig 442) The graft must acquire a new blood supply from the ingrowth of capillaries of the host bed this is in contradistinction to the pedicled flap which is capable when of adequate proportions, of maintaining its vascularization through the pedicle

Indications

A skin graft is a relatively simple method of repairing a defect resulting from superficial tissue loss, as in burns. When a wound with loss of skin cannot be closed by approximation or by a local flap it should be covered by a skin graft. The best dressing for an open wound is a dressing of skin. In some cases as in the replacement of skin of the eyelids or in the relining of the oral and nasal cavities, skin or mucosa grafting is often preferable to the use of pedicled flaps.

Limitations

1 The skin graft does not retain its original size the rate of contraction differs in various locations. Grafts which are placed on a moderately hard base such as the forehead and nose contract less than grafts which are transplanted over looser tissues.

2. Skin grafts are devoid of a subcutaneous tissue layer and are not of sufficient bulk to restore normal contour in certain facial defects.

3 The skin graft is more apt to develop pigmentary changes than the skin flap Pigmentary changes are most striking when skin is transplanted from a distant area such as the abdomen or thigh. The pigmentary changes are of three varieties (a) The graft appears white in contrast to the pinkish hue of the face (Fig 443) (b) The graft is reddish in color the red color usually disappears in time and the skin gradually becomes paler (c) A most marked pigmentary change is that in which the graft becomes dark even a prune juice color Such color changes in females can be camouflaged by the use of cosmetics.

4 Skin grafts are unsuitable when the bed upon which they are placed is not sufficiently vascularized, such as a densely scarred area or bone denuded of periosteum

Development of Skin Grafting

The use of pedicled flaps of skin is a technique as old as plastic surgery whereas the technique of free skin grafting is a relatively recent acquisition Although the ancient Sushruta Samhita in India mentions the use of detached fragments which were transplanted to a new site after slapping the donor area to produce hyperemia before removing the graft, the general clinical use of free grafting dates from the work of Reverdin (1869) It is curious that skin grafting developed so slowly in view of repeated reports of the successful replacement of avulsed or sectioned portions of the nose and ear (see Chapter 4) and the experimental skin grafts in animals reported

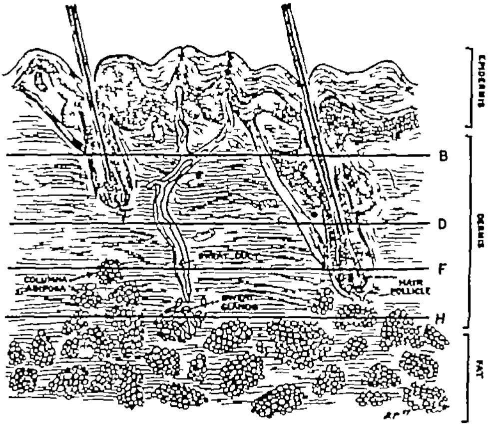

Fig. 442. Comparative thickness of different types of skin grafts.
Level (A-B)—Thiersch graft.
Levels (C-D) (E-F)—Intermediate or split thickness grafts.
Level (G-H)—Full-thickness Wolfe graft.
(J. M. Converse and A. H. T. Robb-Smith, Ann. Surg., 120:873, 1944)

Fig. 443. Example of contrasting color of transplanted skin graft and surrounding tissues of the face.

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The first skin grafting operation appears to have been performed in the United States by Warren in 1840

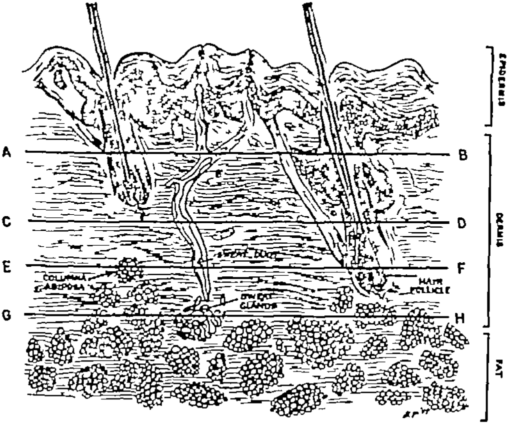
Reverdin a Swiss serving as an intern in Paris, is generally credited with having stimulated the clinical use of skin grafting Reverdin (1869) stated that surgeons had observed an occasional island of epithelium in the center of a granulating area and noted the spreading of epithelium from such an island. He quoted Billroth s belief that these epidermal islands had formed as a result of the survival of a few of the cells of the deep layer of the epidermis. Reverdin attempted to reproduce such islands by means of small transplants of skin which were removed by placing the tip of a stylette into the skin lifting the skin and cutting it very superficially in order to not penetrate into the dermis. Although Reverdin used the term epidermic grafts, he mentioned that he was including not only the epidermis but also a small section of the underlying dermis in his small grafts.

Ollier in 1872, stressed the importance of using not only small grafts as advocated by Reverdin but larger pieces of skin extending over 4 6 or 8 sq cm. and including both epidermis and dermis. Ollier s aim in using such grafts was not limited to creating multiple islands from which epidermis might spread but he also wished to supply a new covering which comprised both dermis and epidermis. Ollier also emphasized the importance of immobilizing the operative site by a plaster bandage and achieved anesthesia of the donor site by means of a refrigerating mixture

Thiersch (1874) described the method of removing thin dermo-epidermic grafts in large sheets to cover wounds and suggested that better success in skin grafting could be attained if the opposed surfaces were already in an excited state. Hirschberg (1893) advised beating the donor site with rubber tubing before excising the graft to induce hyperemia of the part.

Wolfe (1875) described the full thickness graft as follows if we wish a skin flap to adhere to a new surface by first intention or agglutination we must be sure that it is cleansed of all areolar tissue and properly fixed in the new place. The first skin graft was applied to the raw surface which remained after repositioning a severely ectropic lower eyelid. Wolfe performed an experiment in the course of this operation. He left some subcutaneous tissue attached over the undersurface of a portion of the graft and carefully pared off the cellular tissue over the rest of the graft until only the white surface of the dermis was exposed. The portion of the graft with the underlying subcutaneous tissue suffered somewhat during the postoperative period and a portion of the graft was lost the part containing the full thickness skin without subcutaneous tissue was completely successful

Only two types of skin grafts were employed for many years, the thin Thiersch graft and the full thickness Wolfe graft. Davis (1919) modifying Reverdin s technique of removing small superficial pinch grafts, extended the depth of the grafts to include the deeper layers of the dermis or the full thickness of the skin and designated these as "small deep grafts. This technique was a useful adjunct in providing epithelization of raw areas, prior to the development of the dermatome.



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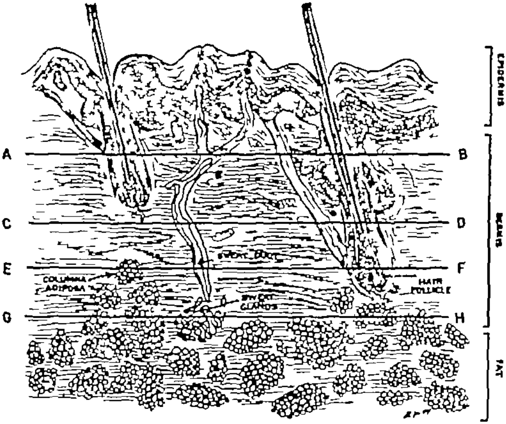

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Interest in skin grafts of intermediate thickness was stimulated by Blair and Brown (1929) who described the split thickness graft. The introduction of Padgett's dermatome (1939) and other mechanical devices for the removal of skin grafts has facilitated the removal of grafts of intermediate thickness.

Types of Skin Grafts

Figure 412 is a diagrammatic section of the skin. The various levels indicate the depths at which different types of skin grafts are cut. The full thickness (Wolfe) graft extends to the level of the fat layer. The Thiersch graft includes only the epidermal layer and a thin layer of the dermis. The intermediate or split thickness graft includes from one third to three-fourths of the thickness of the dermis.

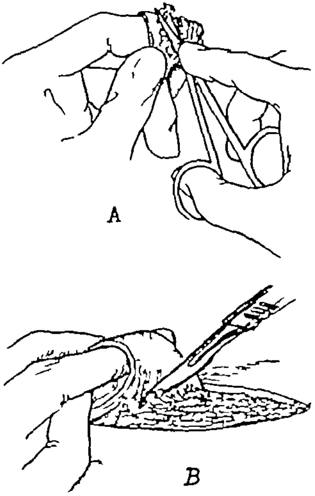


FIG. 411. A. Fat trimmed from full thickness graft exposing the dermis.
B. Removal of full thickness skin graft. Graft dissected along the base of the dermis.

The Full Thickness or Wolfe Graft

The full thickness of the skin is removed from the donor area with a scalpel. The fat must be trimmed away from the base of the dermis to insure success; the fat layer is a barrier to new capillaries which grow into the graft from the host bed. In the reconstruction of eyebrows, full thickness scalp grafts must include the subcutaneous fat to preserve the hairs, for the base of the hair follicle is implanted into the subcutaneous fat. Such grafts, however, must be relatively narrow, because revascularization occurs from the sides rather than from the base of the transplant, where the fat obstructs the penetration of blood vessels from the host bed.

The Wolfe graft is removed by either of two techniques: by transection through the fat, the fat being trimmed from the dermis with scissors (Fig. 411*A*) or by dissection along the base of the dermis, leaving all of the fat in the donor area (Fig. 411*B*). Before the development of the dermatome a favored method of removing full thickness grafts was the so-called "dissected graft" technique. This method consisted of transecting through the deepest layers of the dermis with a scalpel. This type of graft constitutes what Padgett (1939) was later to designate as "the three-quarter thickness" graft.

When the subcutaneous fat is dissected from the overlying skin, the deep surface of the exposed dermis is dead white in color and presents a number of small pits; these are the columnae adiposae which extend upward from the fatty layers into the dermis to join with the base of the hair follicles. When a full thickness graft is removed from a donor area where the skin is thick, about 10 per cent of its deep surface is occupied by the columnae adiposae (Fig. 415). Only 60 per cent of the deep surface is therefore available to receive tissue fluid and the later

ingrowth of capillaries from the defect. Full thickness grafts cut from donor areas where the skin is thin, such as the retroauricular supraclavicular regions or inner aspect of the arm have fewer columnae adiposae on their deep surfaces 80 to 90 per cent of the surface of the dermis is therefore available to receive nourishment from the host bed. This may account for the fact that thick full thickness grafts from the abdomen which are satisfactory only in highly vascular defects often fail at least in part in less vascular areas. A split thickness graft is usually successful in most defects because the fat free dermal surface is available for the reception of tissue fluid and for new capillaries from the host. In order to improve the results obtained with thick grafts Hynes (1954) removed the epidermal layer from a full thickness graft and applied the graft consisting of dermis upside down in the host bed The fat free superficial portion of the dermis, placed in contact with the host bed, is rapidly revascularized by the ingrowth of capillaries. The surface of the graft is covered by a split thickness graft at a later date.

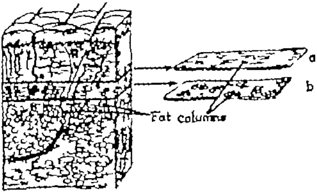


Fig 445 Diagram illustrating that the columns of fat (columnae adiposae) are wider at the base of the dermis (B) than more superficially (A) and impinge upon the surface available for the revascularization of the graft.

Thiersch Grafts and Split Thickness Grafts

The dermatome or other mechanical devices developed for the removal of a skin graft are of assistance especially if the operator lacks experience with the freehand method of removal. The three-quarter thickness graft (Padgett, 1939) in which the dermis is transected toward the base of its dense reticular layer is of a more even thickness when it is removed with the dermatome than when it is obtained with a scalpel The three-quarter thickness graft has all the advantages of the full thickness graft and in addition insures the complete removal of the fat because most of the columnae adiposae are eliminated The revascularization of the graft is comparable to that of the split thickness graft.

TECHNIQUE OF FREE HAND REMOVAL OF GRAFTS. When cutting a free split thickness graft from the thigh the assistant raises the tissue of the donor area thus flattening it to create the surface required for the removal of a wide graft. The operator stretches the skin of the donor area by means of a flat board held in one hand the assistant retracts the skin in the opposite direction with a second board (Fig 446) The skin and a sharp Blair knife are covered with a thin layer of petrolatum jelly the graft is cut at the desired thickness with short rhythmic strokes of the knife the thickness being determined by the angle of the blade in relation to the skin.

REMOVAL WITH CALIBRATED KNIFE. Hofmann (1907) developed a guarded knife in order to obtain grafts of varying thickness, the distance between the guard and the knife being regulated by screws. The first practical skin grafting knife which permitted precise regulation of the thickness of the skin graft was devised by Finochietto (1920) (Fig 447) Humby developed a knife with a roller to maintain the blade at a predetermined depth in the dermis obtaining a degree of calibration (Fig 448) by varying the distance between the roller and the blade. Modifications of the Humby knife are available

THE DERMATOME METHOD By simplifying the removal of the split thickness grafts, the Padgett dermatome (1939) became of inestimable service to the wounded of World War II This method of obtaining skin is

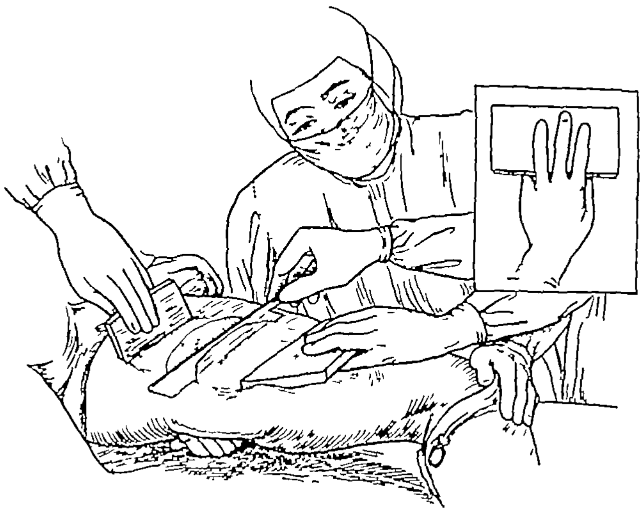


FIG. 446. Free hand removal of split thickness graft. Nurse's hand is placed under patient's thigh to raise the abductor group of muscles and flatten out the donor area.

preferred to all others, the instrument, an important contribution to surgery, is shown in Figures 449–450. The depth of the graft is controlled by regulating the distance between the blade and the drum; a gauge with blades of various thickness permits accurate adjustment of the knife. A uniform layer of cement is spread over the drum and the donor area; the cement is permitted to set for a few minutes in order that adherence of the skin to the drum is assured. The setting time of the cement varies according to its thickness and the hydrometric state of the air; the cement has set when it no longer glistens. A small amount of vaseline is spread

FIG. 447. Calibrated knife developed by Finochietto ([illegible]) to control the thickness of skin grafts.

FIG. 448. Calibrated knife for obtaining skin graft. The knife is preceded by a roller which determines thickness of the graft. By varying the distance between the roller and the blade, calibration of the thickness of the graft is made possible.

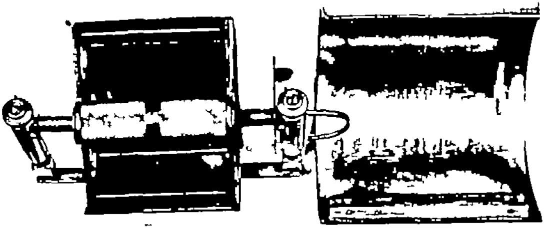


Fig 449 The Padgett dermatome. On the right is seen a large drum which fits over the dermatome in order to remove an over-sized skin graft (6 x 8 inches) (J M Converse, Ann Surg 121 172, 1945)

on the edge of the drum to prevent cutting the skin adjacent to the drum

The drum is applied to the skin and kept immobile for a few moments. Strokes with the dermatome blade then section the skin graft at the desired level (Fig 451) If the graft seems too thick or too thin the calibration can be modified after the cutting has been initiated. Failures are usually due either to cutting the graft before the cement is set or to a dull knife.

The adhesive quality of the cement may cause difficulty in handling the graft when the graft becomes folded upon itself the surfaces adhere to one another the stickiness can be neutralized by rubbing or sprinkling the cemented surface with sulfanilimide powder as the graft is being removed from the drum (Fig 452) Newer types of adhesive cement which do not have this inconvenience are now available.

The graft is also prevented from adhering to itself by a sheet of Pliofilm gauze nylon or special tape (Reese 1946) which is used as a carrier for the skin graft. The backing is cemented to the drum and an additional layer of cement is applied over its surface. The graft is then cut in the usual manner and the sheet of material carrying the graft is gently lifted from the drum

When a pattern is used it is applied upside down to the raw surface of the graft while the graft is on the drum and the outline is marked on the skin with a fine ink line the incision is made along this line in order to obtain the size of the graft (Fig 453) It is more practical however to remove a piece of skin considerably larger than the exact pattern of the defect.

THE REESE DERMATOME. A more heavily constructed precision type of dermatome is that developed by Reese (1946) The drum of this dermatome is covered by a special tape (Fig 454) The dermatape is a specially designed laminated adhesive tape It is attached to the dermatome and the graft is excised directly upon it. After excision the tape and graft are removed from the derma

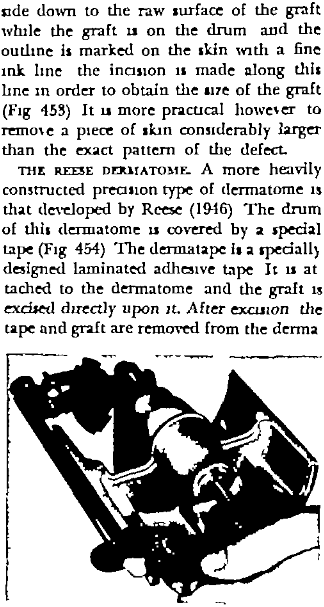
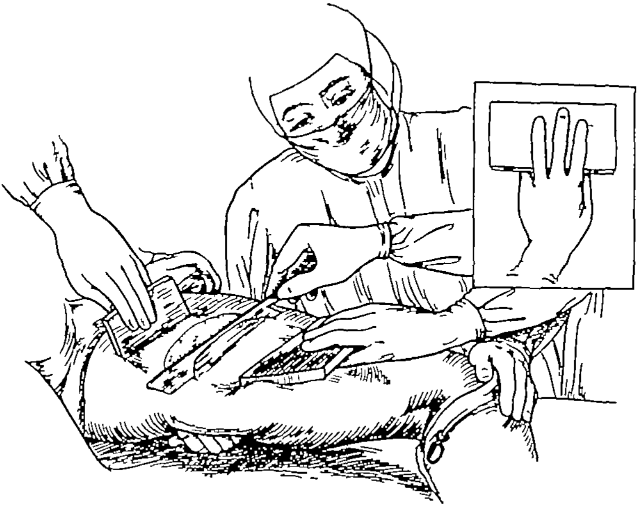


Fig 450 New model Padgett dermatome



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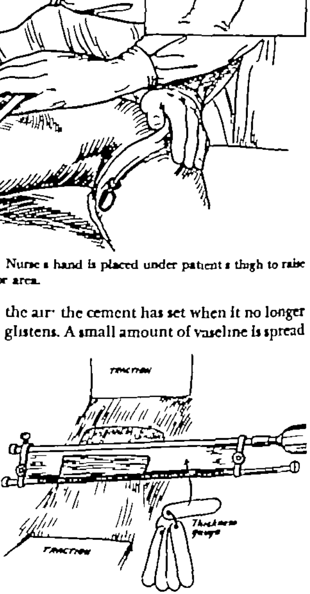

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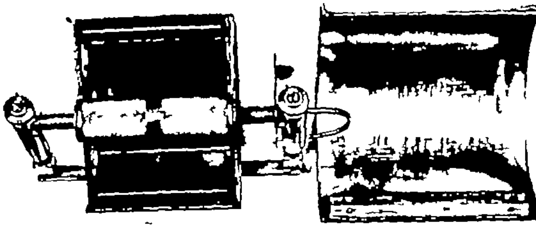

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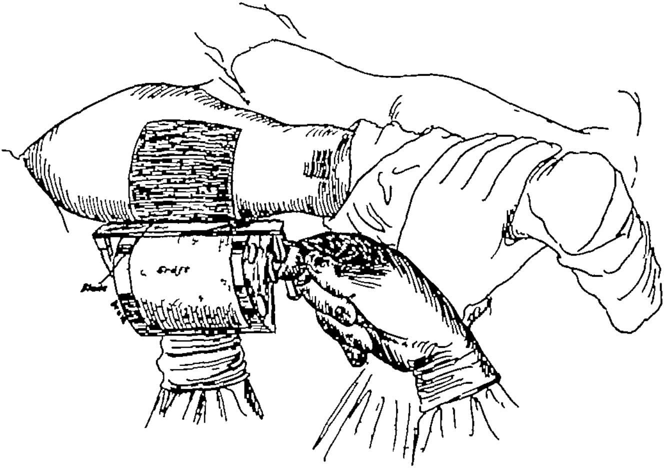

FIG 451 The dermatome. Drawing illustrating graft being cut from postero-lateral aspect of patient's thigh with the dermatome

tome is a unit and the rigid fiberglass backing of the dermatape is removed leaving the graft attached to a pure rubber splint The splint is sufficiently heavy to prevent curling or rolling of the graft, but pliable enough so that the graft can be applied to the wound with necessary coaptation usually without sutures. The splint becomes loosened from the graft in five days and can be removed without difficulty

The surgeon operates and guides the instrument completely controlling the excision of the graft as to thickness and uniformity Shims or thickness gauges, which control the thickness of the graft, are supplied to excise grafts from 0 008 to 0 034 inch in thickness (0.2032 to 0 8636 mm) in gradations of 0 002 inch (0 0508 mm.) The instrument is provided with a sharp throw away precision blade Both the blade and the thickness gauge are so designed that it is impossible to insert them into the dermatome incorrectly

When skin grafting in the region of the face we usually remove the graft from the rubber backing prior to applying the graft to its recipient bed.

The Reese dermatome permits greater precision in cutting calibrated thickness grafts than any of the instruments now available

THE BARKER VACUTOME (1918) This instrument utilizes suction rather than adhesive cement in order to maintain the skin in position while it is being sectioned by the blade at the desired thickness

THE ELECTRIC DERMATOME (1918) This instrument was conceived by Dr Harry M Brown while a prisoner of war in Japan during World War II After the electric dermatome was developed Dr Brown who had just completed his surgical training,

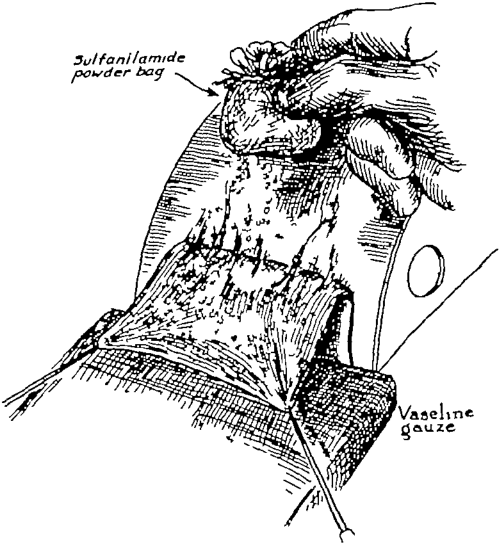

FIG 452 Removal of the skin graft from the dermatome drum. In order to neutralize the stickiness of the cement sulfanilamide powder is sprinkled over the outer surface of the graft.

died tragically as a result of a traffic accident. This skin graft cutting device utilizes electric power to activate the blade. The skin of the donor area is covered with a layer of thin mineral oil to facilitate gliding Calibrated lengthy strips of skin graft may be removed rapidly with this instrument (Fig 455) Although it does not have the precision of some of the other skin graft cutting instruments, the electric dermatome provides a more rapid technique in cutting grafts for resurfacing the raw areas of burns because of the rapidity with which grafts are cut, the patient, often in a precarious condition after extensive burns, need not be maintained under general anesthesia for a long period of time.

The Stryker electric dermatome includes a second roller placed in front of a first roller to increase the area of flattened skin preceding the blade. Other models of electric dermatomes have been designed by Padgett Hood and by McIndoe, in England, and Gosset, in France.

Difficulty may be encountered in removing skin grafts over the thorax with the electric dermatome the preliminary subcutaneous injection of saline solution facilitates the procedure.

The "Split Split Thickness Graft

After removing a fairly thick split thickness graft from the donor area, the graft is left in position on the dermatome the calibration is then changed and the graft is split into two thicknesses. The surface

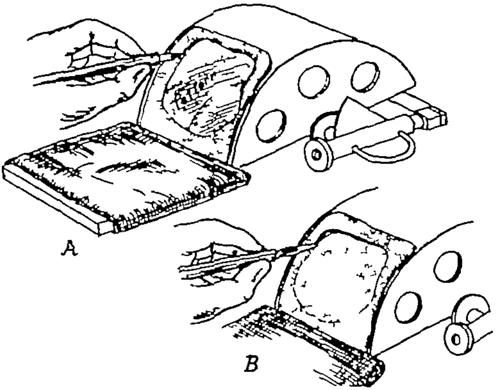

FIG 453 The pattern graft
A. Pattern applied upside down to raw surface.
B. The graft is cut to desired shape on the drum of dermatome

containing the epithelium is used as a thin split thickness graft the deeper layer of the dermis contains a sufficient number of epidermal elements to furnish a new epidermal covering after transplantation (Zintel 1915)

Anesthesia for Skin Graft Removal

General anesthesia is frequently used when split thickness grafts are removed local anesthesia may also be employed. The addition of hyaluronidase in the procaine causes a spread of the anesthetic agent in all directions. An irregular surface due to infiltration is avoided because of the spread the procaine penetrates the fine terminal nerve endings of the skin affording a more satisfactory surface anesthesia than that obtained with the ordinary novocaine-adrenalin mixture A Pitkin automatic refilling syringe is also useful for this purpose as relatively large amounts of solution are required to infiltrate the donor site.

Choice of the Graft and Donor Sites

The selection of a donor site for a skin graft is dependent upon whether a full thickness or split thickness graft is required and also upon the size of the graft. Full thickness grafts for facial repair are best removed from the retroauricular and postaural areas, or from the supraclavicular region. Split thickness grafts are usually obtained from the inner aspect of the arm the medial aspect of the thigh, the abdomen or the back. Whenever possible full thickness grafts should be employed for facial defects and removed from the head or neck regions, because grafts from these areas provide a better match in color and texture than grafts from other areas of the body When larger size grafts are required they must be removed from other areas, usually in the form of split thickness grafts.

Obtaining non hair-bearing skin for grafting presents a problem in some particularly hirsute patients The inner aspect of the arm

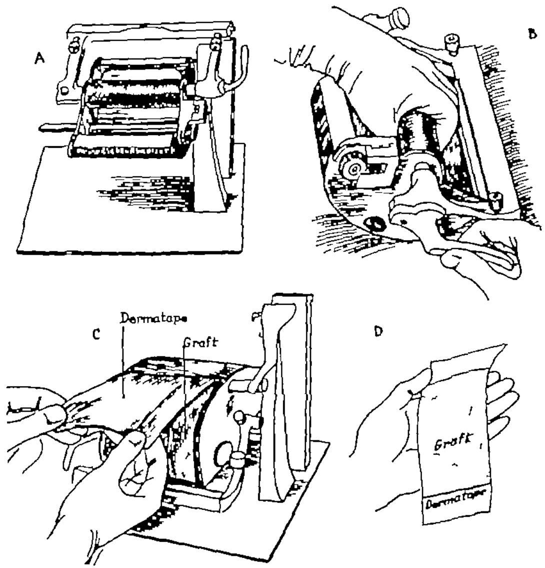

Fig 454 The Reese dermatome

A. Dermatome on stand ready for use.
B. Dermatome applied to skin
C. Dermatape carrying the skin graft removed from the drum
D The skin graft with the dermatape backing

and the lateral aspect of the abdomen are usually devoid of hair

Two favored donor sites of full thickness skin grafts for facial repair are the retroauricular and postaural areas and the supraclavicular region. All of the skin behind the external ear and over the mastoid as far as the hairline, may be removed for grafting purposes (Fig 456) The resultant raw area may be grafted with split thickness skin removed from other areas of the body

Skin Graft Removal in Children

Because the skin of children is thinner than that of adults, the removal of grafts of excessive thickness may result in a full thickness defect in the donor areas Grafts should therefore be cut thinner in children than in adults. Grafts in infants should not be thicker than 0 010 inch (0.25 mm.) in children to the age of six years 0 012 inch (0 30 mm) in older children 0 016 inch (0 40 mm.) Grafts in children are always sufficiently thick because of the marked contraction of the skin after its removal

Postoperative Care of Donor Areas

Donor Area of a Full Thickness Graft

When the defect left by the removal of a full thickness graft is not too large ap-

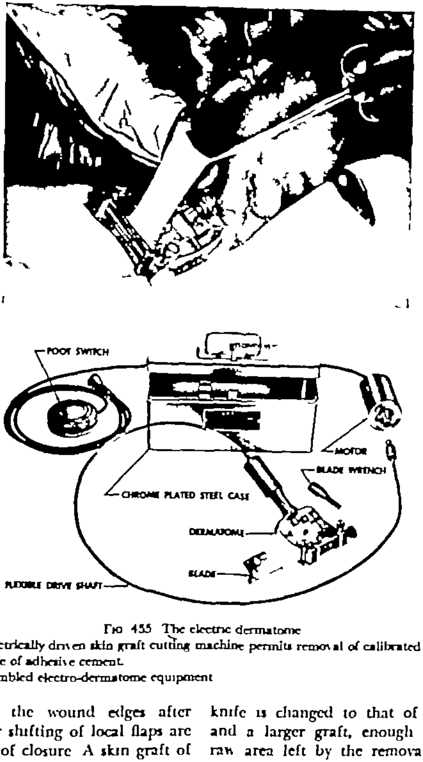

Fig 455 The electric dermatome

(*Upper*) This electrically driven skin graft cutting machine permits removal of calibrated skin grafts without requiring the use of adhesive cement.

(*Lower*) The assembled electro-dermatome equipment

proximation of the wound edges after undermining, or shifting of local flaps are simple methods of closure A skin graft of intermediate thickness is required for large donor areas. A technique for the removal of a large size full thickness graft and the repair of the donor area with a thin split thickness graft follows The dermatome blade is set for a full thickness graft and the cutting of the graft is begun When a full thickness graft of sufficiently large size has been cut the calibration of the knife is changed to that of a thin graft and a larger graft, enough to cover the raw area left by the removal of the full thickness graft, is removed.

Donor Areas of Split Thickness Grafts

Non adherent material sufficiently porous to permit the passage of blood and serum into the absorbent dressing is placed over the bleeding surface of the donor site. These materials are either fine-meshed nylon pet *rolatum gauze and perforated cellophane or*

plastic material Skin graft donor areas should be covered by an absorbent gauze dressing which is firmly anchored by a bandage. Improper fixation of the dressing causes mechanical irritation which interferes with epithelization. A simple method of anchoring the dressing is to paint the skin above and below the donor site with dermatome cement, thus fixing the dressing to the skin Infection of the donor area may result from the accumulation of blood and serum when the area has not been adequately dressed. The dressing should not be completely covered by the adhesive tape, for evaporation of moisture is prevented and serum which favors bacterial growth accumulates.

The dressing if it remains dry should be left in place until cicatrization of the donor site occurs if the dressing becomes stained with blood or serum however it should be removed layer by layer and replaced by dry gauze. An electric hair dryer may be used to blow warm dry air through the gauze of the new dressing to assist in maintaining dryness of the area.

We have recently been employing the open method of treating donor areas of skin grafts more frequently As soon as the skin graft has been removed in the operating room, a current of warm dry air is blown over the area by means of an electric hair dryer until a blood clot has formed. After the patient has been returned to bed it is necessary to protect the area from contact with the bed sheets and to continue the use of the electric hair dryer The donor area covered by a layer of clotted blood which forms a protective crust (Fig 457) remains dry and epithelization occurs with no complications. The patient experiences no undue discomfort, the only inconvenience of the open method is the bleeding from the wound which may stain the bed sheets with blood a condition sometimes affecting the patient's sense of esthetics. If this objection can be overcome the areas heal without complications, and the crust gradually peels away after epithelization has occurred.

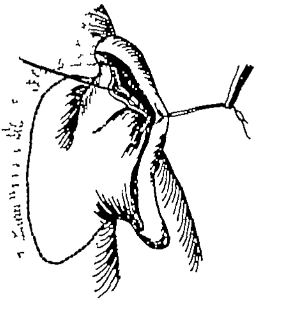

Fig 456. A large full thickness graft can be removed from the postauricular and postaural areas. A graft suitable for transplantation to the face is thus obtained. The resulting defect is covered by a skin graft of intermediate thickness taken from the thigh, suitable to cover the raw area but unsuitable as a transplant to the face.

Fig. 457 Photograph of a donor area treated by the open method. Note the crust which provides a protective covering.

Scarring in the Donor Area

As previously described in Chapter 2 the quality of the skin in the healed donor area depends upon the thickness of the graft and the rapidity of epithelization Condi

tions for prompt re-epithelization are provided by proper postoperative care and when a sufficient number of epidermal elements are preserved in the dermis of the donor area. If an excessively thick skin graft is removed too little dermis is left in the donor area to provide an adequate source of new epidermis Care must be exercised therefore to avoid removing split thickness grafts of excessive thickness. Purposeful removal of a nearly free thickness split thickness graft is permissible if a Thiersch graft is employed to cover the donor area In accidental removal of a graft of excessive thickness, revealed by the presence of lobules of fat appearing between strands of dermal tissue immediate resurfacing of the donor area with a Thiersch graft is indicated Failure to heed this precaution may result in a thick red hypertrophic scar over a portion or all of the donor area an additional painful and pruritent deformity Fortunately most of these hypertrophic scarred donor areas soften gradually becoming paler and free of painful sensations after a period of six months to two years.

Patients predisposed to hypertrophic scars or keloids, and children or adults in the convalescent period following burns, are subject to the formation of considerable thick scarring as the donor areas heal Care should be taken in these patients to avoid the removal of excessively thick split thickness skin grafts in order to permit rapid epithelization of the donor area with minimum scarring Consideration should also be given to the thickness of the skin in the donor area (see Chapter 1) particularly in children and aged individuals whose skin thickness is lesser than that of adults.

Treatment of Infected Donor Areas

When the donor area becomes infected the frequent application of wet dressings of saline or weak boric acid solution has a rapid cleansing effect and encourages epithelization The donor area may be left exposed to the air and dried with an electric hair dryer until a dry protective crust forms. Despite suppuration healing of the area may be rapid after removal of a thin split thickness graft untreated suppurating donor areas heal slowly and with considerable scar formation after removal of a thicker graft

The Recipient Bed

The excision of all scar tissue is the first procedure in the preparation of an area for a skin graft. Dense avascular scar tissue forms an unsatisfactory foundation for penetration of the graft by new capillaries from the underlying tissues is a requisite for success.

Vascular dermis, adipose tissue muscle fascia perichondrium and periosteum are suitable host beds for grafts Bone denuded of periosteum is not a good host bed a stable type of repair is rarely obtained although thin split thickness grafts may become revascularized over bare bone Skin grafts will not survive if cartilage, being devoid of blood vessels is denuded of the vascular perichondrium Other essential requirements for grafting are the absence of suppuration and complete hemostasis in the recipient bed.

Absence of Suppuration

Excision of scar tissue from a healed wound leaves a vascular recipient bed for immediate grafting but in wounds which have remained open for some time and are granulating suppuration must be controlled before success of the graft can be expected. This is accomplished by proper preoperative treatment with wet dressings in addition to the administration of antibiotics. A clinical sign indicating the proper time at which to skin graft a granulating wound is the appearance of a thin layer of epithelium which spreads from the margins of the wound.

The decision to slice or scrape off the outer layer of granulations is determined

by the condition of the granulating area excision may not be necessary if the granulations are flat and non-exudative. If they are hypertrophic, edematous, cyanotic and exudative preliminary excision of the outer layer is a preferable procedure When old fibrotic granulation tissue is present, it is advisable if possible, to excise the entire granulating area down to healthy tissue in order to place the skin graft over well vascularized tissues.

Hemostasis

The graft is applied when active oozing from the recipient bed has ceased Hemostasis should be obtained with as few ligatures as possible or with careful electrocoagulation Compression of the wound with warm saline packs is usually sufficient to control capillary bleeding The application of gauze saturated with adrenalin solution is advisable in some instances to avoid the use of an excessive number of ligatures this applies to both types of recipient areas that left by excision of a scar and the granulating bed Another method consists of applying fibrin foam soaked in thrombin solution under pressure gently removing the foam before applying the graft. Patience is often a requirement the application of the graft should be postponed until the host bed is dry Elevating the patient's head by tilting the operating table assists in the control of bleeding

Delayed Skin Grafting

Because bleeding is profuse *after* the excision of burn scars of the face the risk of hematoma under skin grafts applied to such areas has stimulated interest in delayed skin grafting After excision of the scar tissue the host bed is protected by sterile dressings and skin grafts are applied after an interval varying from 24 hours to a number of days. This technique merits consideration in certain cases.

If a skin grafting operation must be interrupted because of circulatory failure, after the graft has been removed from the donor site and prior to its application to the recipient bed it may be stored in a refrigerator at a temperature slightly above 0 centigrade (see Chapter 15) Excess skin grafts may also be stored for future use

Skin Grafting on a Dermal Bed

The replacement of excess skin grafts over the donor area is an example of grafting onto a dermal bed Superficial excision of layers of the skin with a Blair knife, transecting through the deeper layers of the dermis or removal of the outer layers of the skin by mechanical abrasion are procedures that supply a dermal bed richly vascularized by the dermal plexus vessels. Hynes (1957) has suggested a superficial excision of the soft and pliable superficial scars resulting from the healing of burns The irregular appearance of these scars, which are often spread over wide areas, is objectionable. The covering of the resultant exposed dermis with a smooth layer of split thickness skin graft may improve the appearance of the area (Fig 458) An objection to this technique is a granular appearance of the graft, probably due to the activation of the glandular elements in the underlying dermis. A gradual smoothing out of the graft, however occurs after a period of time by the re-establishment of new channels which permit the outlet of the glandular secretions.

George Webster (1954) has suggested transplanting a second skin graft over a previously healed skin graft. The second graft is placed over the first which has been denuded of its epithelium. This technique of over grafting permits the increase in thickness of the grafted area thus insuring a better dermal blood supply and an improved appearance

Combined Auto- and Homografts of Skin

In the skin grafting of large defects following deep burns, when a sufficiently large skin surface is not available for autografting strips of autografts may be alternated with

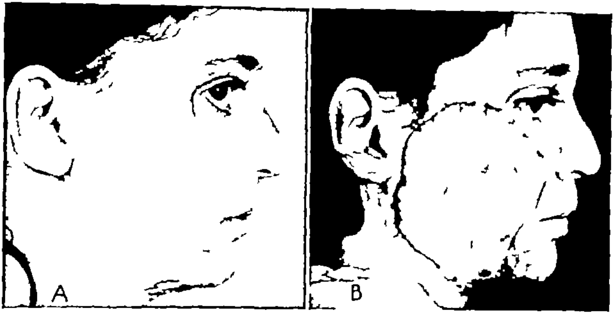

Fig 458. Skin grafting on a dermal bed

A. *Irregular surface scars of the cheek resulting from burns.*

B. Appearance of split thickness thin skin graft from the thigh 12 days after being applied to mechanically abraded scarred area.

strips of homografts. This procedure, generally attributed to Mowlem provides an immediate complete coverage of the raw areas with cessation of wound exudation and temporary surgical closure As the homografts are rejected the spreading epithelium from the autografts covers the resultant raw areas.

Fixation of the Graft

A full thickness graft should be spread evenly over the raw area and attached to the wound edges by fine sutures. Accurate *approximation can be obtained with interrupted* sutures, but the procedure is accomplished more rapidly with a continuous running suture. A three point suture is useful in applying the graft in the groove between the skin edge of the defect and the recipient bed. The needle is passed through the graft through the tissue of the recipient bed and then through the skin edge (Fig 459*A*) if the edge of the defect is thick the three-point suture may be placed through the base of the dermis (Fig 459*B*) This technique obliterates the dead space which results from the tenting of the graft over the groove along the edge of the defect this is the danger zone in skin grafting the area where the graft is most frequently unsuccessful The three point suture technique is employed in both interrupted and continuous sutures. Such accurate approximation is not necessary with Thiersch and intermediate thickness grafts. It is even desirable to overlap the periphery of the wound to make certain that the entire raw area is covered the excess skin is excised later

A more rapid technique in split thickness *grafting consists of applying the epidermal* surface of the graft to a backing of petrolatum gauze and the backing carrying the graft is placed over the defect, the edges overlapping the defect. In another technique the backing material of nylon gauze or Pliofilm is glued to the drum of the dermatome additional cement is then added over the surface of the backing material in order to remove the graft The Reese dermatome technique provides a backing of special tape

In closed cavities, such as the nasal and oral cavities and the eye socket it is not

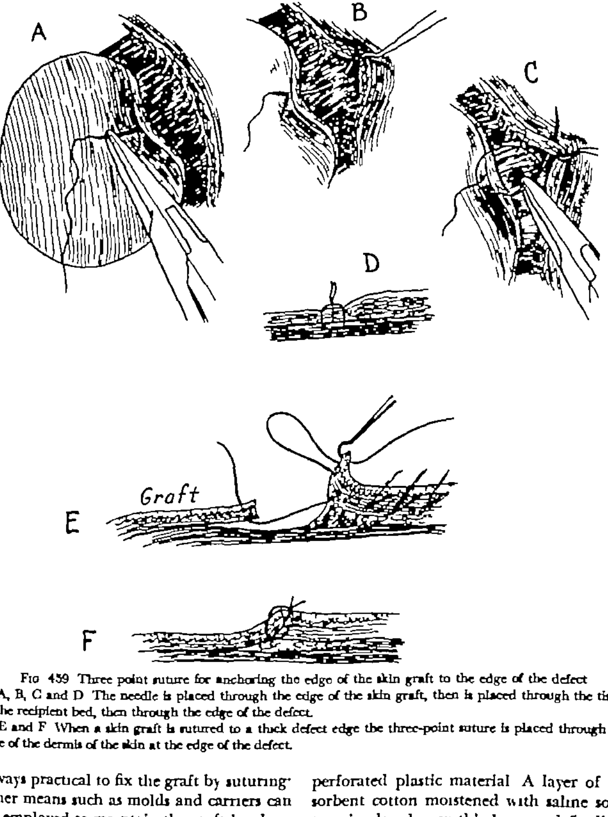

Fig 439 Three point suture for anchoring the edge of the skin graft to the edge of the defect

A, B, C and D The needle is placed through the edge of the skin graft, then is placed through the tissue in the recipient bed, then through the edge of the defect

E and F When a skin graft is sutured to a thick defect edge the three-point suture is placed through the base of the dermis of the skin at the edge of the defect

always practical to fix the graft by suturing other means such as molds and carriers can be employed to maintain the graft in place

The Dressing

Although petrolatum or glycerine gauze is a good non adherent covering for a skin graft, the authors prefer to use a non-greasy non adherent covering such as nylon or a perforated plastic material A layer of absorbent cotton moistened with saline solution is placed over this layer and finally a sufficient amount of dry, fluffed-out gauze or mechanics waste and a cotton pad is applied to build a pressure bandage Since the cotton absorbs saline solution easily the dressing may be removed with the least amount of trauma to the newly grafted area

by remoistening the cotton Cotton which has been soaked in mineral oil and wrung out dry in small pledgets is also used as a dressing in lieu of the saline packs.

Immobilization and Pressure

Immobilization and pressure are requirements for wound healing these conditions *are essential in skin grafting* Without immobilization the skin graft becomes displaced folded upon itself or lifted from its bed and new capillaries which are growing into the graft are torn. Without adequate pressure a collection of blood or serum forms between the graft and the bed and the portion of the graft which is detached from its bed is lost through necrosis.

Excessive pressure has resulted in necrosis of skin grafts over the forehead the entire *area becomes ischemic and the local* blood supply is inadequate to revascularize the graft.

Close coaptation of the graft to the bed over the less mobile portions of the face and head is maintained by constant pressure of materials such as cotton wool sponges, mechanics waste or fluffed-out gauze, compressed by means of bandages with some degree of tensile strength in order to retain compression. Elastic pressure is preferable because *the elastic dressing adapts itself to* irregularities in the graft bed the pressure dressing is self adjusting if motion occurs.

The Tied In Pressure ("Bolus") Dressing
(Galtier 1937)

Sutures are placed along the edges of the defect and the ends are tied over the dressing thus attaining complete fixation of both graft and dressing (Fig 460) The tied-in pressure dressing also draws the bed of the *graft up against the graft and the overlying* dressing thus increasing the intimate contact between graft and bed

Regional Immobilization

After skin grafting the entire region must be immobilized by carefully applied dressings and bandages. Mobile areas on the side of the face in the region of the cheek, chin and neck are more difficult to immobilize. In addition to the application of a pressure dressing in these areas, it is advisable to soften dental compound, to spread it over the gauze and to apply a pressure bandage while the compound is soft the compound, *when hardened, aids in the distribution* of an even pressure over the entire surface and prevents wrinkling of soft tissues caused by the pressure bandage.

Movements of the mandible may be prevented by intermaxillary wiring, and close co-operation of the patient may be obtained when the patient must avoid moving the lips, cheeks or jaws these precautions are carefully explained prior to the operation. It may be judicious, in some cases, to employ *transnasal feeding through a Levine tube* during the first days after a skin grafting operation of the face in order to avoid movements of the jaw and deglutition which might interfere with the healing of the skin graft

Immobilization in the area of the head and neck is not as easily achieved as in the extremities where a plaster splint or cast provides complete immobilization It is occasionally necessary to apply a plaster cast *in order to immobilize the neck the cast* over the trunk has an upward extension to immobilize the neck and prevent rotation movements of the head

Epithelial Inlay

A skin graft in the oral nasal or orbital cavities can be immobilized by means of a mold of dental compound This technique was termed epidermic inlay by Esser (1917) He used the method to restore an oral vestibular sulcus which had been obliterated in a gunshot injury of the mandible He made a submandibular external incision and dissected the soft tissues and oral mucosa from the bone and then employed a mold of dental compound surrounded with a Thiersch graft The mold

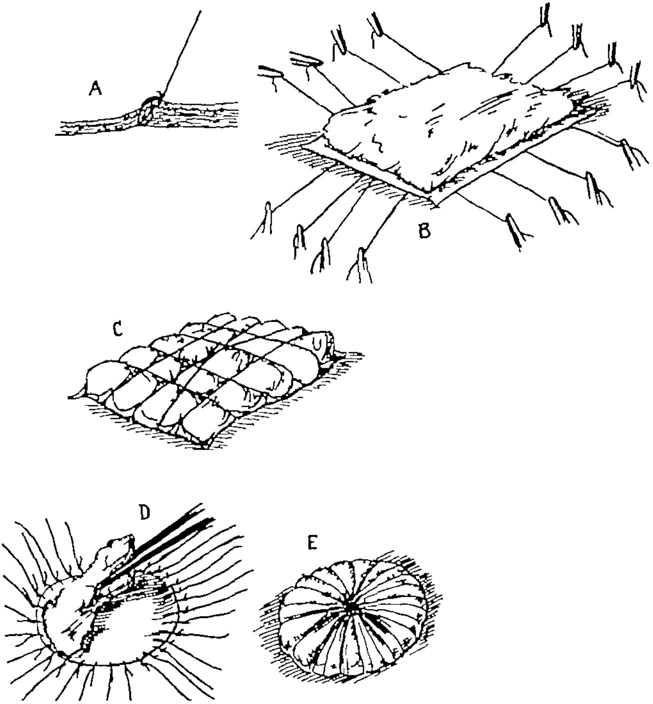

FIG 460 Tied-in (bolus) dressing to provide fixation of the pressure dressing to the graft
A. Vertical mattress suture employed in approximating the skin graft to the edge of the defect.
B. Sutures held while pressure dressing is applied over the graft.
C. Sutures tied over the pressure dressing
D and E. Circular defect skin grafted and tied-in dressing applied

carrying the graft was placed into the subcutaneous cavity and the skin wound sutured. At a later date he incised the oral mucosa in the oral vestibule removed the mold and thus established communication between the oral cavity and the newly created skin grafted sulcus.

Waldron working at Sidcup with Gillies conceived the idea of introducing the skin covered dental compound mold directly through the oral cavity (Fig 461) He incised the adherent tissues in the oral vestibule took an impression of the resultant cavity with softened dental compound, permitted the mold to harden and after applying the skin graft, raw surface outward, to

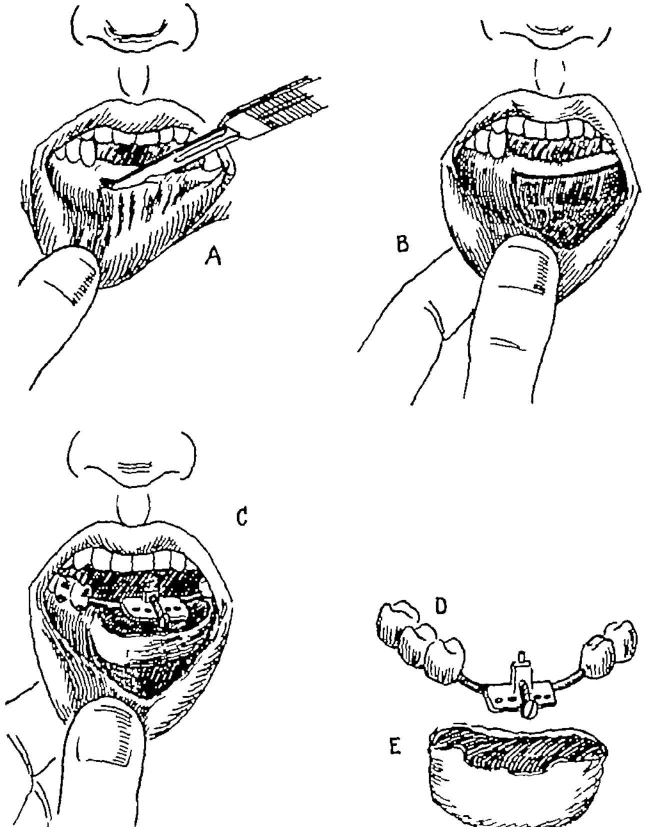

FIG. 461 The epithelial inlay technique to provide a new buccal sulcus

A. Typical scar obliterating the sulcus.
B. Incision close to alveolar crest, freeing the lip.
C. Dental compound mold held by a metal plate fitted to cap splint by a screw attachment.
D. Cap splint with screw attachment.
E. Compound mold holding skin graft.

(After H. D. Gillies, *Plastic Surgery of the Face*. Oxford Medical Publications 1920)

the mold, immobilized it until healing occurred. This technique known as the epithelial inlay has been in general use since

Epithelial Outlay

The technique was modified by Gillies (1918) for skin grafting in burn ectropion of the eyelids. He undermined the edges of the defect and spread softened dental compound over the host bed and under the undermined edges of the defect the hardened mold served as a carrier for the skin graft. This technique permits grafting an excess of skin to allow for late contraction (Fig 462)

First Postoperative Dressing of a Skin Graft

Considerable divergence of opinion exists concerning the proper time at which to undertake the first dressing after a skin grafting operation A dressing at too early a stage causes unnecessary traumatization of the healing skin graft undue delay in doing the first dressing may result in maceration infection and suppuration of the skin grafted area. A good practice is to leave the dressing undisturbed for 5 to 8 days if no signs of complications have developed Exploration of the dressing consists of removing the pressure bandage and some of the outer dressing in order to examine the edges of the skin graft. A complete change of dressing is indicated if exudation is noted. If the grafted area appears dry the outer dressing and pressure bandage are replaced and a further period of immobilization follows.

Failure to immobilize the graft for a sufficient period of time results in rupture of the delicate newly formed blood vessels growing into the graft. Such small hematomas, which appear as blood blisters, may result in ulceration and local infection thus accounting for the partial failure after the initial success of the graft.

The length of the immobilization period depends upon whether the graft is thin or

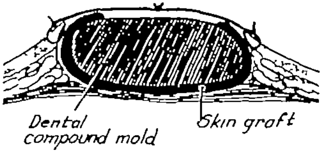

Fig 462 The epithelial outlay technique. The edges of the defect are undermined, thus increasing the surface to be grafted. The mold is maintained by sutures tied over it.

thick and whether it is derived from a well vascularized donor area or a relatively less vascularized region.

Thin grafts for the relief of ectropion of the upper lid are so well vascularized by the third or fourth postoperative day that dressings may be dispensed with thereafter A full thickness graft of thin and vascular retroauricular skin requires only six or seven days of immobilization because the graft is rapidly revascularized A more slowly vascularized full thickness graft of abdominal skin for example, may require fourteen days of immobilization if the graft shows desquamation of the epidermal layer and exposure of the dermis it must be slowly nursed back to a healthy state.

The Healing of Skin Grafts

The process of healing or to use the clinician s term the take" of a skin graft, is essentially that of revascularization which insures survival of cells in the graft by the inflow of nutrient elements and the outflow of waste products. The establishment of blood flow in the graft permits regeneration of new cells by the multiplication of surviving cells, and also by the increment of new cells to replace dead cells. The vascularization of skin autografts and homografts is described in Chapter 15 the early events prior to the ingrowth of blood vessels into the graft, usually referred to as plasmatic circulation " are also discussed.

The skin has a blanched or dead white appearance immediately after removal from

the donor site because it is devoid of blood *The color of the graft changes within a few hours* becoming a pinkish hue through the absorption of fluid from the host bed into the endothelial spaces of the graft

When applied to the recipient bed the graft is fixed by a layer of fibrin and becomes adherent within five hours. The connection with the recipient bed is firm and complete within the first ten days. Collagen is fairly abundant and begins to increase at the expense of the fibroblastic elements. During subsequent days and weeks the maturation of the collagen in the layer of scar between the base of the dermis of the graft and the recipient bed causes contraction a diminution in size and sometimes wrinkling of the overlying graft this late contraction is more pronounced in thin than in thick grafts, and also occurs more readily in regions where the tissues are loosely attached to the underlying structure as for example, in the cheek.

Histological sections of grafts show that the survival of a skin graft depends upon the balance between degenerative and proliferative changes during the revascularization of the graft (see Chapter 15). The process of regeneration is more rapid in thinner grafts partial loss of the outer layers is less frequent than in thicker grafts. In thicker grafts, particularly in the full thickness graft, blebs form and areas of epithelium exfoliate, which may lay bare the underlying dermis resurfacing by a new layer of epithelium must occur before the graft can be considered healed The blebs often uncover small areas of necrosis and ulceration these may easily become infected Such necrotic areas are usually situated over a blood clot. Areas of localized epithelial loss and ulceration leave superficial scars with some degree of contraction and often pigmentation

The thin layer of scar beneath the graft is responsible for the rigidity of skin grafts in their early stage the wrinkling of the grafts, and their glistening appearance Flattening of the epithelium and partial disappearance of the irregular junction line *between the base of the epithelium and the* dermal papillae probably explain the smooth and glistening appearance of skin grafts by obliterating the normal surface corrugations of the skin.

Skin grafts become softer in time because of alterations in the underlying layer and dermis. A layer of fat begins to appear within two or three months after skin grafting About a year and a half after skin grafting the transplanted dermis is infiltrated *with elastic fibers these fibers, however do* not assume the orderly appearance seen in *normal skin These changes coincide* with regeneration of nerves in the grafted area, return of the pain sensation touch heat, and the reappearance of sweating The changes improve the texture pliability and appearance of the graft although the color match is usually not improved the graft tends to become "naturalized" to the surrounding skin in time (Fig 463)

Because of the inactivity of sebaceous and sweat glands in transplanted skin the use of lubricants such as lanolin cold cream or coconut butter is indicated until reinnervation of the graft reactivates these cellular elements.

Gentle massage of the grafted skin assists in smoothing softening the transplant and rendering it more pliable and mobile

Hair Growth in Transplanted Skin

Rapid regrowth of hair has been cited as one of the evidences of cellular survival in skin grafts. When skin is transplanted either by the pedicled flap method or by free skin grafting abnormal hair growth requires removal for esthetic or functional reasons, for example if hair is transplanted in an area such as the oropharyngeal cavity The presence of hair may also interfere with adequate healing or functioning of skin lined tubes in a reconstructed esophagus. Avoidance of hairs in transplanted skin is dependent upon the choice of a hairless donor area *The lat*eral aspects of the abdomen and back and

FIG 463 Example of naturalization of a graft after a period of two years
(*Left*) Granulating area from burn
(*Center*) Appearance of skin graft two weeks after transplanatation
(*Right*) Appearance of graft two years after transplantation.

the inner aspect of the thighs and arms are hairless in most individuals Skin grafts should be cut very thin in lining the oral cavity or the conjunctival sac to avoid removing hair follicles with the graft. The entire body appears to be covered with hairs in some male patients the medial aspects of the arm, however are usually hairless.

The stimulus that causes hair follicles to increase in size is unknown In grafts containing only lanugo hair such hairs are capable of becoming well-developed long hairs after transplantation.

The destruction of hairs in transplanted skin may be accomplished by a variety of methods. Hair is usually absent in areas that have received x radiation therapy· radiation may be used therefore for the destruction of hair follicles. Most surgeons feel that this method is dangerous because the dose of radiation required for the destruction of the hair follicle may cause later radiation dermatitis.

Electrolysis is a method frequently used and necessitates the introduction of a fine needle into each hair follicle· it is a painstaking method, but is used successfully when the number of hairs to be destroyed is not too great.

Surgical epilation can be used by raising the skin graft or flap over a portion of its surface in order not to interfere with the blood supply to the transplanted tissue The hair follicles can then be removed by one of three methods (1) The base of the hair follicle is removed by excising the subcutaneous adipose tissue (2) hair follicles may also be plucked out by seizing the base of the bulb of the hair with eyebrow tweezers and (3) the exposed hair follicles can be treated by diathermy coagulation destroying each hair follicle bulb (Garcia 1954)

Surgical excision of the hair bearing skin is a relatively simple method of epilation either closing the defect by direct approximation or by a local flap or skin graft. In the reconstructed ear for example long hairs are frequently seen growing from transplanted split thickness grafts An oval shaped excision around the hairy area closes the defect by direct approximation A small full thickness graft from a hairless donor area can be employed if such a closure is not feasible.

Sebaceous Collection under Skin Grafts

Sebaceous material may collect under a skin graft due to burying the cut ends of the

glands beneath the graft. Due to the lack of innervation in skin grafts, the sebaceous material accumulated in the glands cannot be evacuated by contraction of the arrector pili muscles. These collections can be evacuated after a small incision is made in the skin

Wrinkling

Wrinkling is apt to appear about the *third or fourth week in split thickness* grafts, but usually smooths out over a period of approximately six months.

Nerve Regeneration in Transplanted Skin Flaps and Grafts

According to Löfgren (1951) Dubreuilh and Noël as early as 1911 demonstrated sweating in a full thickness graft 15 months after transplantation Kredel and Evans (1933) drew attention to the fact that the return of the sweating function occurred very late in tubed pedicled flaps Kredel and Phemister (1939) studied the recovery of sympathetic function in pedicled skin flaps and reported that sweating occurred after 11 months at the earliest the time and degree varying in different cases. Free skin grafts showed less ability to recover sympathetic function

Skin transplantation is successful only after the functions of the skin have been restored—these include recovery of sensation and sweating Functional sympathetic regeneration of practical value occurs in full thickness skin grafts but regeneration is never complete for transplanted skin never attains the high quality of normal skin Functional sympathetic regeneration like superficial sensation seems to be induced in the graft centripetally from the surrounding skin over the transplant. Scar tissue hinders the ingrowth of nerve fibers this factor was *demonstrated by De Castro (1929)* in experimental animals He showed that nerve fibers, encountering a scar in their path never attain their goal but spread out into the scar tissue The highest degree of functional sympathetic regeneration occurs in pedicled flaps. There are few signs of regeneration in split thickness skin grafts. This may be accounted for by the fact that the position of the sweat glands in the depth of the dermis and in the subcutis precludes their inclusion in the split thickness graft.

Löfgren (1951) noted than transplanted skin of whole thickness began to regain softness and become oily at about the same time that sweating reappeared. The return to the normal oiliness of the skin is a sign of regenerating sebomotor function In contrast Thiersch grafts remain dry and parchment like this is due not only to the inadequate nerve regeneration but also because the greater part of the sweat and sebaceous glands are not included in the thinner grafts.

Pain and tactile sensitivity return earliest in full thickness grafts whereas the thermal sensation shows signs of recovery at a considerably later period. Pain sensitivity seems to accompany the returning sweat secretion. Signs of the reappearance of superficial sensation in split thickness grafts are still weak up to 49 months after grafting Pain sensitivity alone can be demonstrated in very small areas. As observed by Guttman a border zone reaction may be shown by means of the dye test, a compensatory hyperactivity of sweat gland function along the border of the slightly sweating surface of the graft

An investigation of the function of regenerated somatic sensory nerves in grafts (Hutchison Tough and Wyburn 1949) suggested that the nerve fibers growing into the graft are capable of causing the differentiation of end organs, that is, touch spots *in situ* when they reach the appropriate zone of the dermis. A similar sequence of events does not occur in the case of pseudomotor sympathetic fibers, since no new glands are formed in the graft Sympathetic fibers can only reinnervate glands that are already present Sweat glands are not restored when a wound heals by granulation

It can be assumed that the sweat glands which are transplanted in grafts and flaps survive and are ultimately reinnervated after the ingrowth of the sensory nerve fibers. Although the graft retains the anatomical pattern of the donor skin it acquires the physiological sweating pattern of the recipient site.

Contraction of Skin Grafts

Skin grafts contract immediately after their removal from the donor site this contraction is designated as *primary* contraction secondary contraction occurs after healing of the graft.

Immediate or Primary Contraction

Elastic fibers in the dermis account for the contraction which occurs when a skin graft is cut and released from the tension of the surrounding skin. The thicker graft, because it contains more dermis includes a larger amount of elastic tissue the contraction is therefore greater Measurements of the immediate contraction of skin grafts made by Davis and Kitlowski (1931) before implantation into the recipient bed have shown that a thin Thiersch graft, containing very little dermis, contracts about 2 per cent. Thicker grafts contract from 11 to 24 per cent, and a full thickness graft as much as 43 per cent. The skin of young patients is richer in elastic fibers and is capable of a greater degree of contraction than that of older patients. Immediate contraction is greater in the direction which is parallel to the lines of tension of the skin. The skin graft is stretched to its original size, however after the graft is spread over the wound and sutured in place

Late or Secondary Contraction

Secondary contraction of a skin graft results from maturation of the scar which unites the graft to its recipient bed. Contracture is a gradual process during the weeks which follow skin grafting, and is influenced by the following factors

1 THE THICKNESS OF THE GRAFT If the graft is thick, less contraction occurs. Late contraction is minimized when the dense, deep reticular layer of the dermis is included in the graft.

2. THE NATURE OF THE RECIPIENT BED When a graft is laid over a soft mobile area such as the cheek, contraction occurs more readily than when the graft is placed over a firm base such as the forehead.

3 PARTIAL FAILURE OF THE GRAFT Areas of ulceration in the graft heal by contraction of the surrounding skin When superficial loss of a part or all of the epidermis occurs, healing takes place by epithelization which originates from the remaining islands of epithelium or from the epithelial elements of the dermis and by inter island contraction (see Chapter 2)

The tendency to secondary contraction of the free skin graft is an important factor in reconstructive surgery Early satisfactory results often prove disappointing later because of contraction which leads to the formation of folds, hypertrophic scars or in severe cases, to contracture and deformity Experimental investigations conducted in rabbits have shown that secondary contraction of full thickness grafts of rabbit skin reaches its maximum after one month and subsides after two months (Ragnell 1952) The manner in which the graft is rotated when sutured to the host bed seems to exert

FIG 464 Castroviejo's modification of Da Silva's electric dermatome for the removal of calibrated split thickness grafts of mucosa

little influence upon the degree of contraction

Grafts of Mucosa

Mucosal grafts are used to replace conjunctiva and nasal mucosa and to line the eye socket The usual source is oral mucosa for only small grafts can be obtained from the conjunctiva of the opposing eyelid or the homolateral conjunctival sac. The most suitable donor site is the inner cheek wall because the mucosa is thinnest in this area the graft is usually obtained by excision of a full thickness piece of oral mucosa. An incision is made along the buccal groove and a rectangular piece of mucosa including the submucous tissue is removed with a knife The graft is thinned over the finger as in a full thickness graft until the desired thickness is obtained. A piece of buccal mucosa as large as 2.5 by 5 cm may be removed from each side of the cheek wall without causing contractures or adhesions within the oral cavity

The removal of calibrated split thickness mucosal grafts from the inner aspect of the lower lip can be achieved by means of Castroviejo's (1959) modification of the small electric dermatome developed by Da Silva (1957) (Fig 461)

Advantages

The mucosal graft is the graft of choice in the conjunctival sac, especially since the development of mechanical means by which thin split thickness mucosal grafts are made available (Fig 461) A skin graft in the conjunctival fornix when the globe is present, is likely to result in keratinization to cause corneal irritation and because of the presence of sebaceous secretions, emit a fetid odor

Mucosal grafts are also preferable to skin grafts for use within the nose because a skin graft becomes dry and is susceptible to crust formation

Disadvantage

The excessive thickness of oral mucosa which has been cited as a disadvantage of this type of graft, can be overcome by trimming the deep surface of the graft with scissors, until the desired thickness is obtained The use of the electric dermatome has obviated the complication of excessive thickness of mucosal grafts.

19

GRAFTS OF DERMIS, FAT, FASCIA, CARTILAGE AND BONE

Dermis, fat, cartilage and bone are highly specialized connective tissues which bind and support other tissues. Connective tissue is developed from mesenchyme, a subdivision of the mesoderm and consists of a larger content of intercellular substance than epithelial tissue the various types of connective tissue differ in the content of their intercellular substance

Connective Tissue Fibers

Three types of fibers occur in adult connective tissue. (1) White fibers which consist of collagen, an albuminous substance the fibers are composed of bundles of extremely fine fibrillae When immersed in dilute acids or alkalis the intrafibrillar cement substance of the collagen fiber is dissolved, separating into its constituent fibrillae (2) Reticular fibers are small branching fibers frequently forming a net like supporting framework or reticulum which may be demonstrated by silver staining techniques (3) Elastic fibers, homogenous highly refractive fibers, branch and anastomose freely forming networks. Chemically they consist of elastin They may be colored deeply by specific dyes such as orcein and resorcin fuchsin.

The Ground Substance of Connective Tissue

The ground substance of connective tissue is a non fibrillar homogeneous substance which varies from a fluid like to a gell like consistency The ground substance and tissue fluid, a plasma like substance, surround the fibrillar elements and cells of connective tissue Connective tissue contains a mucopolysaccharide hyaluronic acid. An enzyme hyaluronidase, hydralizes hyaluronic acid, reducing its viscosity with a consequent increase in the permeability of the tissue The addition of hyaluronidase to local anesthetic agents assists in spreading the solution throughout the tissues

DERMAL GRAFTS

The dermis varies in thickness between 0.2 to 4 mm and is composed of dense irregularly arranged connective tissue. The dermis consists of a relatively thin papillary and a thicker reticular layer and is composed of coarse collagenous fiber bundles which unite to form secondary bundles The dermis is the nutrient membrane of the epidermis containing a rich vascular network and many epidermal elements hair follicles, sebaceous glands sweat glands and ducts.

Dermis has been employed as a filling material to add soft tissue padding and to restore contour in depressions caused by scars or loss of subcutaneous tissue The dermal graft consists of the dermis alone it may also include the subcutaneous layer of fat or the fascia lata and is then designated as a dermal fat graft or a dermal fat-fascia graft.

Loewe (1913) and Rehn (1914) were the first to advocate the use of dermis for the repair of anatomical defects in postopera

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Loewe (1913) and Rehn (1914) were the first to advocate the use of dermis for the repair of anatomical defects in postopera

tive hernias. Loewe studied such grafts in approximately one hundred patients over a 15 year period and found that the grafts healed and became firmly attached

The burying of a dermal graft in a subcutaneous bed with its epithelial inclusions, hair follicles, sebaceous glands, sweat glands and ducts has aroused controversy The formation of inclusion cysts, continued secretion of sebaceous material and the introduction of infection from bacteria contained in hair follicles and sudoriferous glands, were considered to be complicating factors Peer and Paddock (1937) made histological sections of dermal graft fragments removed at various intervals after transplantation and stated that these epithelial cysts attain only microscopic size and are not significant. Clinically however we have seen small inclusion cysts develop in rare cases. Infection from epithelial inclusions is not a major hazard in our experience and

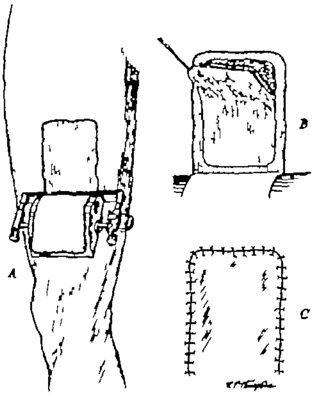

FIG 464 Diagram illustrating the removal of a dermal graft

A. A Thiersch graft is cut but left attached at end

B. The dermal graft including fat is removed

C. The superficial layer replaced and sutured in position.

according to experimental studies (Harkins, 1945)

Full thickness skin grafts have also been employed as subcutaneous implants When skin is buried under the surface of the skin it tends to curl on itself toward the surface epithelium forming a closed cavity an epithelium lined tube or cyst (Davis and Traut 1926 Zinches, 1931) Good results have been achieved by the use of free full thickness grafts in the repair of hernias (Mair 1945) Marsden (1948) and Zavaleta and Uriburu (1950) also attained good results with no cyst formation Strahan (1951) in four hundred thirteen cases of hernia treated by skin grafts, reported that although cyst formation was present in a significant number of cases this complication did not justify discontinuation of the method.

The sebaceous glands are located superficially near the epidermis. Most of the sebaceous glands can be eliminated from the dermal graft by de-epithelizing the dermis this is accomplished by removing a Thiersch graft from the outer surface of the skin The use of such a preliminary de epithelized graft is preferable to that of a graft consisting of the whole thickness of the skin

Scarred skin has been buried successfully (Reid, 1952) an accomplishment which may be accounted for by the fact that scar tissue is devoid of the usual epidermal inclusions in the dermis

Technique

Many hair follicles are implanted deeply in the dermis and even into the subcutaneous tissue The donor tissue should therefore be chosen from a relatively hairless portion of the thigh or abdomen or the buttocks. An area of skin slightly larger than the desired dermal graft is raised with the dermatome and left attached by one side (Fig 465) The skin is split at a thickness of 0 008 to 0 012 inch (0.20 to 0 30 mm) The underlying dermis and adipose tissue of de

sired, are removed with a scalpel A graft removed from the lateral aspect of the thigh may consist of dermis fat and fascia lata. An alternate technique is to remove a thick graft, 0 040 to 0 050 inch (0.916 to 1 0 mm) on the dermatome and reset the knife blade to remove a Thiersch graft 0 008 inch (0.20 mm.) in thickness from the surface of the tissue thus obtaining a pure dermal graft of even thickness. The dermal graft is placed in the defect and anchored by a few sutures the introduction of the graft into the bed is facilitated by the use of traction sutures (Fig 466) Numerous layers of dermis may be employed to obtain adequate correction

We have used dermal grafts to fill depressions caused by a deficiency of subcutaneous tissues in the mobile portions of the cheek and encouraging results have been obtained in restorative treatment of hemiatrophy of the face. The rate of absorption necessitates large quantities of dermis to allow for shrinkage Because of this fact one cannot be certain of the eventual contour of the grafted area Repeated dermal grafting may be necessary to achieve a durable result, because of the absorption of the dermal graft. Peer (1958) has suggested the preliminary delay of a pedicled flap comprising skin and subcutaneous fat prior to the removal of a dermis-fat graft from the flap Greely (1958) has employed a de-epithelized tubed pedicled flap inserted subcutaneously in the face (Fig 467)

Bone or cartilage grafts are preferable in the contour restoration of bony defects because of the degree of absorption of dermal grafts

FAT GRAFTS

Adipose tissue or fat differs little from areolar tissue except that it contains a much higher percentage of cells disposed to store fat. It has partitions of collagenic and elastic fibers extending through it. The partitions carry arteries and veins into the adipose tissue arterioles and venules enter the lobules from these partitions and separate into extensive capillary networks which supply the fat cells.

Fat grafts have been employed to elevate depressed scars in order to reshape facial contour, and to obliterate dead spaces. Fat grafts have been found unsatisfactory by many surgeons because of the high absorption rate. The absorption may be accounted for by the relatively poor blood supply of fat The grafts are revascularized slowly thus accounting for their absorption Investigations have shown that the graft is reduced by one-half to one fourth of its original size, that the reduction is dependent to a degree on the trauma to which the graft is submitted during transplantation and that multiple small grafts un

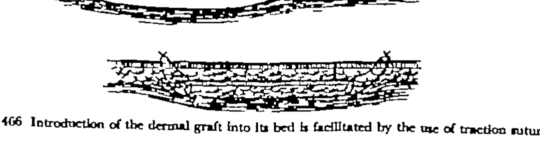

FIG 466 Introduction of the dermal graft into its bed is facilitated by the use of traction sutures

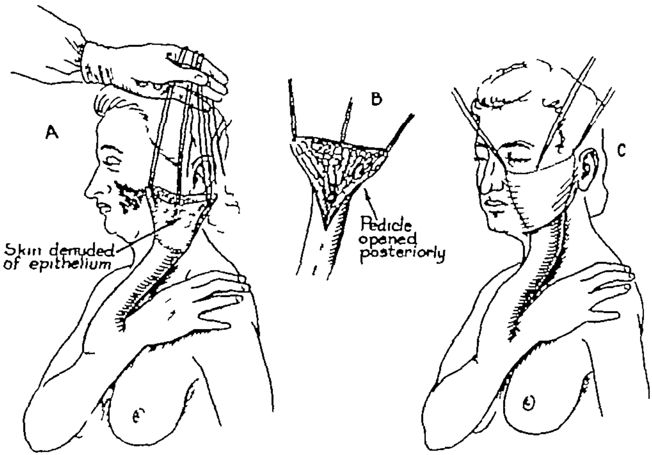

Fig 467 Tubed pedicled flap to provide dermal-fat graft.
A. Tubed flap from the abdomen, de-epithelized.
B. Tube opened posteriorly
C. Tube inserted subcutaneously through a submandibular incision At a later stage the flap is severed and the submandibular incision is closed.
(Modified after P W Greeley 1958)

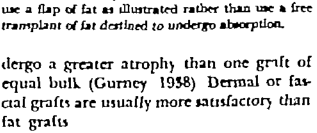

Fig 468 In depressed wounds it is preferable to use a flap of fat as illustrated rather than use a free transplant of fat destined to undergo absorption.

dergo a greater atrophy than one graft of equal bulk (Gurney 1938) Dermal or fascial grafts are usually more satisfactory than fat grafts

Technique

The fat is removed through an incision in the skin of the thigh or abdomen When fat is obtained from the thigh, fascia lata is also included in the graft for it has more stability The graft is introduced into the deficient area with a minimum of trauma the skin is sutured, and a dressing of moderate pressure is applied to prevent hematoma

A pedicled flap of fat can be used to fill a depression in order to preserve the blood supply to the fat in areas where adipose tissue is abundant (Fig 468) This technique is particularly useful for building up the chin (Fig 469) and cheek the rate of absorption being much less than that which occurs in free grafts of fat especially if the pedicle is wide It is often possible to utilize two flaps of fat turned in from the undersurface of the tissue lat

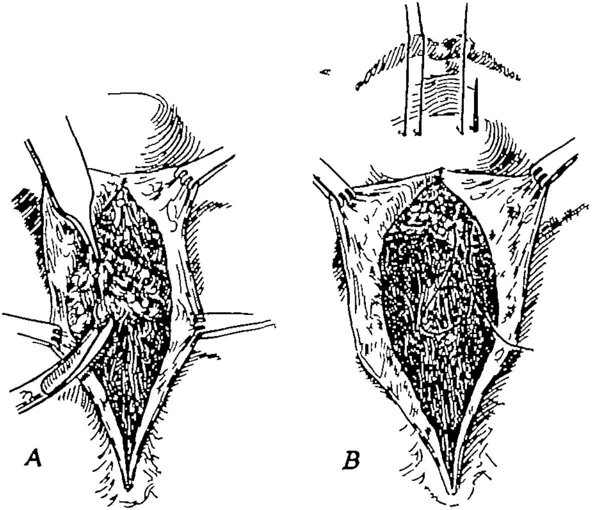

FIG 469 Transposition of a flap of fat from under the chin to form the prominence of the chin
A. An area of fat is dissected from its underlying attachments but left attached above.
B. The fat flap is transposed to the chin area by means of mattress sutures.
(V H. Kazanjian, New England J Med. 215 1104 1936)

eral to the edges of the wound, to elevate depressed scars.

Another method is to raise a tubed pedicled flap from the abdomen and transfer the flap to the face via the arm. The tube is de-epithelized before the insertion of the flap into the face (Greeley 1958) An incision is then made along the lower portion of the defect the skin over the depressed area is undermined, the tube is opened and the flattened flap is inserted under the skin to fill the area (Fig 467) A similar result can be obtained with a non tubulated closed carried or jump flap (see Chapter 17)

FASCIAL GRAFTS

Fascia lata is composed almost entirely of collagenous fibers arranged in parallel fashion and packed closely in bundles forming sheet like structures which bind other structures of the body The most frequently used fascial graft is the fascia lata of the thigh

Since Kirschner (1909) advocated the method, other types of fascia have been employed such as the fascia covering the temporalis muscle. Fascia lata was advocated for the repair of hernias by Gallie and LeMesurier (1924) and as a means of suspending the paralyzed face by Blair (1926)

Fascia lata is used as an interposition material after resection of the mandibular condyle or of a section of bone from the ramus in temporomandibular ankylosis to furnish suspension straps in facial paralysis in ptosis of the eyelids and as a filling material to restore general contour Fascia

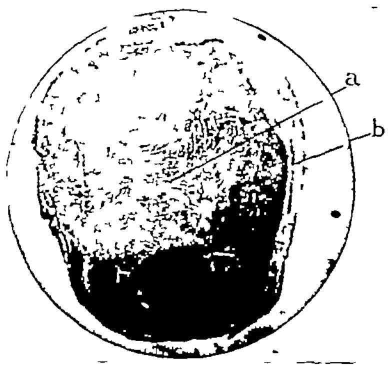

FIG 470 Cross-section of fascial suture after six weeks (low power) The suture is now a rounded cord. The separate folds can no longer be distinguished, and the new tissue between them is represented merely by narrow trabeculae of connective tissue.

a. *Rounded cord of fascial suture*

b. Vascular areolar tissue. (Courtesy of Dr W E. Gallie.)

is superior to dermis and fat for filling small depressed areas for it is absorbed to a lesser extent

The transplanted fascia shows signs of inflammatory reaction during the first few weeks The blood vessels dilate in the tissue surrounding the transplant and a capsule composed of spindle-shaped cells and fibers encloses the fascia during the week after transplantation During this period few changes other than edema occur The inflammatory reaction gradually subsides after the third week No cellular or fibrous changes have been observed (Gallie and LeMesurier 1924) (Fig 470) in sections of fascia lata made one year after transplantation Peer (1955) has observed autogenous fascial grafts buried in fat for a period of eighteen months He is of the opinion that cellular division occurs in fascial grafts, indicating cell survival mass infiltration by host fibroblasts was not observed.

Snyderman (1957) studied fifty-nine frozen-dried fascia lata homografts 56 of these homografts were employed for the repair of thoracic and abdominal defects three were applied as suspension slings in patients with facial paralysis who have been followed over a 3-year period. All of the fascial homografts gave satisfactory results serving the purpose for which they had been introduced

Technique

Strips of fascia lata are obtained by dissection through an incision along the lateral aspect of the thigh The fascial stripper is used if long strips are desired (Fig 471) The stripper is provided with a guillotine which permits sectioning the upper attachment of the fascial strap without the need for an additional incision The lower end of the iliotibial band is exposed through a small transverse incision and a slip of fascia is sectioned and threaded into the stripper the instrument is then passed along the thigh stripping the fascia in its path the fascial strip is then sectioned and

Fig 471 Wilson fascial stripper permitting removal of fascia through a small incision as shown in Figure 472.

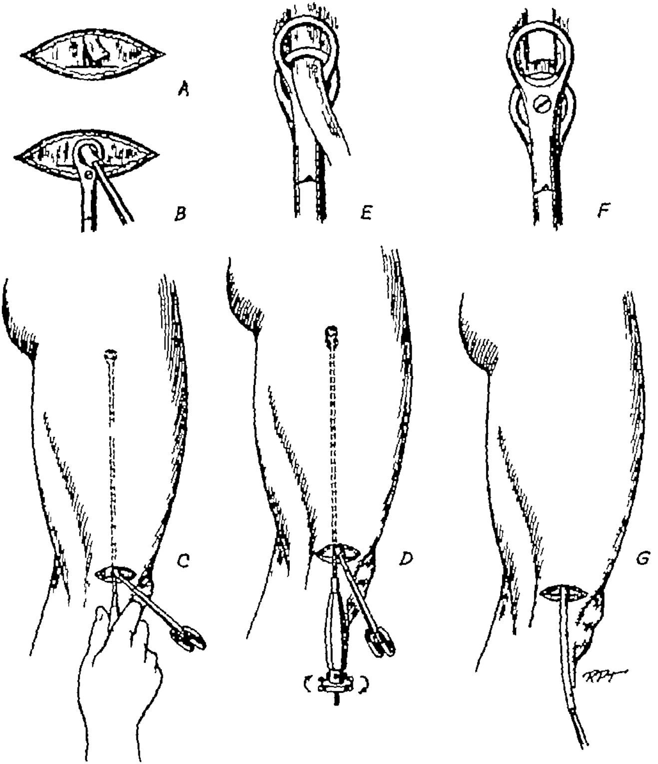

Fig 472. Removal of strip of fascia lata with fascial stripper

A. Incision started at distal end of fascia lata.
B. End of fascia pulled through stripper
C. Stripper carried up thigh.
D E, F Blades of stripper detach proximal end of strip.
G Freed strip of fascia withdrawn

removed (Fig 472) The strip of fascia lata must be divided into narrower strips for use, for example as suspensory loops to support a paralyzed face The best method to accomplish this is to tear the fascia longitudinally in the direction of its fibers. A cut with scissors separates one end of the fascia into two parts these are grasped with moist gauze and separated again by tearing along the direction of the fibers The procedure is repeated until a sufficient number of strips of adequate caliber are obtained

Fascial strips used as suspension straps appear to remain intact in the paralyzed face (see Chapter 27) but may stretch and increase in length with time the strips may require secondary tightening years after transplantation.

CARTILAGE GRAFTS

Cartilage is specialized connective tissue possessing considerable tensile strength and the ability to bend if required to bear weight Cartilage consists of a fairly dense network of collagenous fibers and in some instances, elastic fibers for tensile strength The fibers are embedded in and perhaps chemically united with a considerable quantity of amorphous intercellular substance which is in a state of a very firm gel (Ham 1953)

Cartilage grafts were first transplanted in experimental animals by Paul Bert (1865) Ollier (1867) noted that experimental perichondrial grafts in animals failed to produce cartilage and that grafts devoid of perichondrium did not survive when transplanted from one animal to another According to Nélaton and Ombrédanne (1907) von Mangold appears to have been the first to use a cartilage graft On October 5 1897 he removed a portion of the eighth costal cartilage about 3 cm long and 1.5 cm wide and used this cartilage graft in conjunction with a flap to reconstruct a laryngeal defect He used an autogenous cartilage graft to repair a saddle nose on June 21 1899 according to Peer (1939)

König used an autogenous cartilage graft in 1896 and in 1902 expressed the opinion that cartilage which has no blood vessels, can continue to survive under rather unfavorable conditions of nutrition Morestin (1916) utilized grafts of costal cartilage to repair defects in the cranial wall and facial skeleton and found that such grafts hold and retain their health and bulk" for years after transplantation

Cartilage grafts are indicated to provide a cartilaginous framework in the reconstruction of the ear and nose and also for contour restoration of bony defects of the facial skeleton and cranium

Types of Cartilage

Of the three main types of cartilage, hyaline elastic and fibrocartilage hyaline is the most common and best serves as a prototype of the group costal cartilage is an example of hyaline cartilage It has a gross pearly white glassy translucent appearance, due to the special character of its intercellular substance. The word hyaline derived from the Greek hyalos, means glass

Hyaline cartilage consists of cells and intercellular substance Chondrocytes, cells with a rounded nucleus and one or more nucleoli are found in intercellular spaces known as lacunae The cytoplasm fills the lacuna in the living but is commonly seen to be shrunken away from the sides of the lacuna in stained sections.

The intercellular substance of hyaline cartilage appears homogenous in many microscopic preparations and contains a quantity of both formed and amorphous material The formed kind is represented by collagen fibers which are immersed in a relatively large quantity of amorphous intercellular substance known as chondroitin sulphuric acid Young chondrocytes are often flattened rather than spherical Old or fully differentiated cartilage cells tend to be large and rounded

Cartilage is completely surrounded by

perichondrium a connective tissue membrane which consists of densely arranged collagenous tissue in its outer portion and cartilaginous characteristics in its inner portion It is often difficult to determine where the inner portion of the perichondrium ends and the cartilage begins.

Hyaline cartilage is not quite so elastic as cartilage which contains elastic fibers in its intercellular substance, such as auricular cartilage

Hyaline cartilage forms the cartilages of the nose larynx trachea bronchi and the costal cartilages Almost all of the skeleton is laid down initially in the fetus as hyaline cartilage and is then replaced later by osseous tissue

The external ear Eustachean tube epiglottis and some of the laryngeal cartilages contain elastic cartilage Cartilage with greater tensile strength, fibrocartilage occurs in certain parts of the body as for example in a tendon insertion The meniscus of the temporomandibular joint is an example of fibrocartilage

Nutrition of Cartilage

Cartilage is a non vascular tissue The capillaries are found in the perichondrium of the cartilaginous structures. Chondrocytes are nourished by means of substances which diffuse into the gelled intercellular substance surrounding them The invasion of cartilage by capillaries is generally associated with its calcification and absorption

The matrix degenerates if the cellular elements fail to survive transplantation but if the cellular elements survive, the matrix remains

Fresh costal cartilage, sectioned and stained with hematoxylineosin shows the centrally located chrondrocytes considerably contracted from the walls of the lacunae due to fixation The more peripherally located spindle-shaped cartilage cells often appear quite normal It is therefore difficult in sectioned and stained preparations to determine whether the cartilage is alive or dead If fresh cartilage is sectioned and shavings are placed in normal saline under a cover glass on a slide direct examination under the microscope will show that the centrally located chondrocytes completely fill their lacunae (Peer 1955) The cells in the section die under the heat from the light undergoing dessication similar to that which occurs through the action of a fixative the cells contract from the walls of the lacunae and when stained appear similar to the cells in ordinary fixed and stained cartilage The best test to determine the vitality of the cells of a cartilage graft is to examine a freshly sectioned piece if the cells completely fill the lacunae they can be referred to as living cells

Clinical Use of Cartilage Autografts

Cartilage has been used widely as a filling material to build up the contour of the nose chin zygomatic area for reconstruction of the ear and for the repair of small cranial defects Cartilage autografts do not require contact with adjacent cartilage for survival and for this reason are of particular value A drawback however to the use of certain types of cartilage, such as costal cartilage is that occasional curling or twisting after transplantation occurs

A moderate cellular reaction occurs around the graft following transplantation A connective tissue capsule which contains fibroblasts in the process of multiplying and numerous dilated blood vessels form around the cartilage (Peer 1941) In sections which have been removed and examined a number of years after transplantation the fibrous capsule is still present, neither resorption nor invasion of autogenous cartilage by fibrous tissue having occurred

Cartilage Homografts and Heterografts

Viable cartilage homografts have been employed cartilage homografts from a liv

FIG 473 Photomicrograph of cartilage homograft 15 months after transplantation. Cartilage homograft in the form of an auricular cartilage removed from patient s father and transplanted for a reconstruction of the ear The transplanted cartilage became softened failing to give support to the reconstructed ear Pyknosis of the nuclei and invasion of the periphery by connective tissue are observed.

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Cartilage homografts preserved by deep-freezing dessicating, immersion in alcohol or Merthiolate solution (O Connor and Pierce 1938) have also been transplanted in the non viable state.

The use of cartilage for homografts par ticularly preserved cartilage has the ad vantage of a ready supply of available implant material without submitting the patient to an additional operation to remove an autogenous graft.

Gibson Curran and Davis (1957) using the uptake of S35 as a test of viability found a normal uptake of the isotope for a period up to 7 months in viable cartilage homografts in man These observations and those of Dupertuis (1941) on the growth of cartilage homografts taken from young rabbits confirmed by Bacsich and Wyburn (1947) suggest that the possibilities of physical persistence of living homografts of cartilage are greater than those of devitalized preserved cartilage homografts and confirm the histological observations of Peer (1955).

Our experience with both fresh and preserved cartilage homografts is that they have a tendency to soften and become in vaded by fibrous tissue histological exami nation reveals degeneration of cells. Figure 473 shows the microscopic appearance of a fresh cartilage homograft fifteen months after transplantation

Cartilage heterografts have been advocated by Gillies and Kristensen (1951). Ox cartilage is obtained from the xiphisternum of 18-month-old heifers and placed in a solu tion of merthiolate (1 4000) According to North (1953) Gibson and Davis (1953) and Schofield (1955) preserved cartilage homografts and heterografts are absorbed in a high proportion of cases. The rate of absorption of cartilage heterografts is greater than that of cartilage homografts. Histological study of disintegrating heterografts of carti lage shows that they are invaded by connec tive tissue blood vessels and many giant cells are observed

Cartilage homografts and heterografts can be considered therefore, as temporarily well tolerated foreign bodies probably superior to inert foreign materials because they consist of organic material less likely to cause reaction leading to their final rejection. They may be tolerated by the tissues for a variable period of time if they are not implanted in areas of functional stress or subjected to muscular movements or trauma. The authors regard the clinical use of both cartilage homografts and heterografts as representing a second-best type of procedure which is not justified in most cases. The patient with a facial deformity deserves an operative procedure which provides a permanent result.[1] The ultimate absorption of a dead cartilaginous implant leaves a bed of scar tissue which renders secondary repair of the deformity much more difficult. Such cartilage homografts should be reserved for exceptional cases as emergency implants, when the removal of autogenous grafts is contraindicated and occasionally in children if the implant is serving as a temporary prosthesis.

Technique of Removing a Cartilage Autograft

Small pieces of cartilage can be removed from the auricle or from the nasal septum larger grafts are obtained at the junction of the seventh eighth and ninth rib cartilages

An incision is made through the skin beneath the sternum, over the lower border of the common cartilage of the seventh eighth and ninth ribs. The skin incision should be placed horizontally in one of the natural skin folds to minimize subsequent scarring If the incision is medial the fibers of the rectus muscle are split longitudinally and the edges of the muscle retracted to expose the perichondrium the external oblique muscle may be severed if the incision is placed more laterally When large cartilage grafts are to be removed the rectus muscle is cut transversely to obtain better exposure An incision through the perichondrium is made in the shape of a double T the perichondrium is elevated and retracted and the cartilage is removed. The edges of the severed muscle are approximated after hemostasis by placing sutures through the edges of the covering fascia subcuticular sutures are placed to relieve tension on the skin suture line

Kelly Gouge Technique

When relatively small grafts are required, as for a nasal transplant, cartilage may be removed with a gouge of approximate size (Fig 474 Kelly 1927) This technique has the merit of facilitating the removal of the cartilage and diminishing the risk of pleural perforation

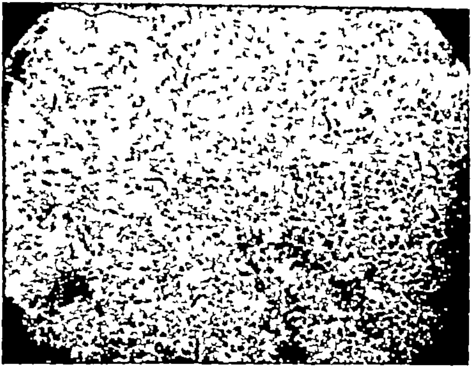
Resection of the Whole Thickness of the Costal Cartilage

A similar incision to that described above is employed to obtain exposure of the rib cartilage The cartilage is freed by circumferential elevation of the perichondrium with a raspatory and the required quantity is then resected (Fig 475) A section of cartilage with the attached perichondrium is removed when large amounts of cartilage are required In some cases particularly in ear reconstruction the entire thickness of two adjacent ribs may be required The cartilage is removed extraperichondrially from the lower portion of the common cartilage of the ninth and tenth ribs (see Chapter 28)

Pleural Tears in Costal Cartilage Resection

Careful technique is required to avoid the danger of pleural puncture when removing rib cartilage. Should the pleura be punctured or torn pneumothorax is prevented by an increase of pressure through the closed system of anesthesia which maintains the lung in an expanded state.

A traumatic pneumothorax is not a serious complication in patients with good respiratory function of the opposite lung but all patients being operated upon for removal of a cartilage graft should be an



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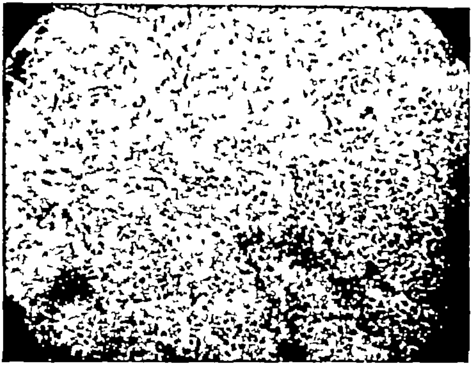

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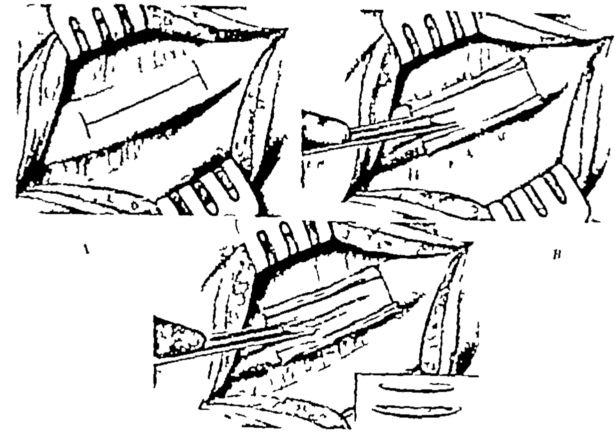

Fig 474

A. Showing exposure of rib with incisions made in the perichondrium

B. Removing cartilage for simple transplant.

C. Showing the method of removing the cartilage for the cases in which the cartilage is required to be grooved (Kelly gouge technique)

esthetized in the closed system Expansion of the lung can be maintained by the anesthesiologist in this manner after a traumatic pneumothorax has occurred As soon as the opening in the pleura is discovered aspiration is employed to suck the blood from the pleural cavity and the tear is closed with silk sutures. If closure of the pleural tear is not feasible closing the muscle layer over it usually suffices. Re-establishment of lung function occurs within a few days after the pneumothorax Michelson's technique (1950) consists of intrapleural cavity catheter drainage at the time of the occurrence of the tear The tear is closed by the expanding lung by this procedure the pneumothorax is obliterated and the fluid seeping into the pleural cavity is removed rapidly

Advantages and Disadvantages of Cartilage Grafts

A subcutaneous pocket is prepared for the cartilage graft or grafts which are to be introduced The cartilage may be transplanted in various forms (1) in one block, (2) in multiple pieces or (3) in diced form (Peer 1941) in accordance with the type of deformity

Autogenous cartilage grafting is the procedure of choice in reconstructing cartilaginous structures such as the external ear or the lower cartilaginous portion of the nose *Cartilage is also indicated as a contour* restoring material in bony depressions of the face when contact between a bone graft and surrounding healthy bone is not possible

Cartilage grafts have certain inconveniences. Costal cartilage tends to curl upon

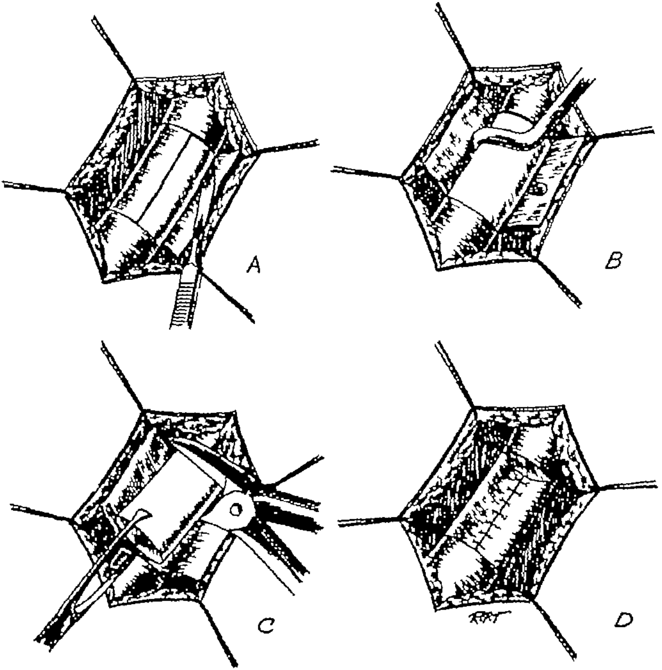

Fig 475

A. Double T-incision in perichondrium.
B. Raspatory worked back and forth to free cartilage from perichondrium.
C. Section of rib cartilage removed.
D Closure of perichondrium. (After Lexer)

itself The use of septal cartilage, which does not present this inconvenience, remains the procedure of choice for filling depressions over the lower cartilaginous portion of the nose. In addition to curling, cartilage presents the inconvenience of being subjected to the pull of the surrounding soft tissue scar in the course of healing, and is apt to be twisted or rotated during the weeks following implantation (see Fig 708 Chapter 22)

BONE GRAFTS

Bone is a rigid variety of connective tissue which forms the skeleton of the body Like cartilage and other forms of connective tissue bone consists of cells, collagenous fibers and a ground substance which be-

comes impregnated with calcareous material The inorganic material responsible for the rigidity of bony tissue is composed of calcium phosphate calcium carbonate and small amounts of calcium floride and magnesium chloride

Structure of Bone

Spongy and compact varieties of bone do not represent two distinct types of osseous tissue histologically but differ only in the degree of porosity (Ham 1953) the spaces are large in cancellous bone and the bony substance is reduced to slender spicules and bars. The histological character of the cells and the intercellular substance is similar in both cancellous and compact bone The surface of the bone is surrounded by the periosteum a vascular fibroelastic membrane The outer bone is compact the innermost area is a medullary cavity which encloses a marrow space The endosteum or inner periosteum of the marrow cavity is not a histologically distinct membrane but is formed of concentrated medullary connective tissue

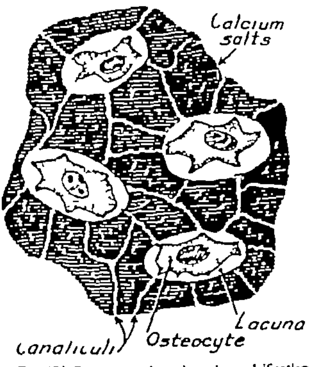

Fig 476 Diagram to show that when calcification occurs the canaliculi remain patent to conduct tissue fluid to the osteocytes

(After A W Ham, *Histology* Ed 2 J B. Lippincott Co 1953)

The structure of adult bone tissue is characteristic, the fibers and calcified matrix being organized in layers or lamellae The compact osseous tissue of long bones is traversed by the Haversian canals longitudinal channels which anastomose with each other by oblique and transverse communications. Volkmann's canals, narrower canals from the periosteal and endosteal surfaces pierce the bone obliquely to its long axis and communicate with the Haversian canals, thus establishing an elaborate canal system for the blood vessels and nerves of the bone

The bone cells are located in flattened cell spaces or lacunae situated between or within the lamellae The canaliculi form delicate channels of communication joining the cell spaces with the other bony channels. Thus in addition to the network of larger channels which convey the blood vessels, a system of minute canals consisting of lacunae and canaliculi serves as passageway for nutrient fluids (Fig 476). Osteoblasts are imprisoned in the bone as it forms and become bone cells or osteocytes.

The structure of bone consists of cells in lacunae surrounded by intercellular substances similar to cartilage there are however fundamental differences between the two tissues. The intercellular substance of bone unlike that of cartilage is permeated by a system of canaliculi which extend from one lacuna to another and to bony surfaces where capillaries are situated Tissue fluid from the capillaries permeates the canaliculi and nourishes the cells in the lacunae (Fig 476) Bone differs from cartilage being vascular and well-supplied with capillaries The organic intercellular substance of bone is usually calcified whereas if cartilage becomes calcified its nutrition seems to be affected and the cartilage degenerates

The Formation of Bone

Ossification or osteogenesis depends upon the presence of osteoblasts. These cells be

come surrounded by the intercellular substance and are thenceforth referred to as osteocytes.

Not all of the osteoblasts differentiate into osteocytes many proliferate on the periphery of the bone. Trabeculae new bone processes join together to form cancellous bone If the covering osteoblasts continue to proliferate and differentiate forming osteocytes, new bone is added to the free ends of the trabeculae increasing their length The new bone is deposited in layers designated as lamellae The continued deposition of lamellae may transform cancellous bone with large spaces into compact bone with narrow spaces. Bone tends to be arranged in concentric layers surrounding a canal thus forming the Haversian system which consists of units of compact bone Each canal contains blood vessels, providing tissue fluid to nourish the osteocytes in the surrounding lamellae

Clinical Use of Bone Grafts

Bone grafts have been employed extensively to re-establish the continuity and function of the mandible, to repair cranial defects and also as a contour restoring material for bone defects of the face.

Bone grafts consolidate rapidly with the host bone and become incorporated into the bony framework of the face so much so that in subsequent roentgenographic examination it is often difficult to differentiate the bone graft from the bony framework. Bone grafting is contraindicated only if contact between the bone graft and living bone cannot be achieved.

History of Bone Transplantation

Interest in the regeneration of bone was aroused during the eighteenth century and bone transplantation was first attempted during the nineteenth century The history of early observations and experimentation in this field has been told by Keith (1919) Opinion regarding the growth of bone was divided between those who with Duhamel Syme and Ollier regarded the periosteum as the chief osteogenic element of the human skeleton the "maternal membrane of bone, to use Ollier's term and those who with Goodsir and Goodsir (1845) and Macewen (1912) regarded the osteoblasts of the graft as the source of osteogenesis for Macewen the periosteum was a mere limiting membrane Ollier had demonstrated the osteogenic power of detached fragments of periosteum in animals and concluded from observations made in experimental fractures that the periosteum is the chief agent in forming the callus that the marrow plays a lesser role in the process and that the bone itself is the least factor in callus formation. In 1878 Macewen removed the entire humeral diaphysis of a 3-year-old boy affected with osteomyelitis, restoring the shaft of the humerus with wedges devoid of periosteum which he obtained in the course of tibial osteotomies performed on other patients he reported this first recorded example of the clinical use of homogenous bone grafting In 1881 Macewen performed a series of operations on animals and published his results in 1912 thirty years after he had begun to use fragments of bone as grafts.

The contention of Macewen that the osteoblasts of a graft are the source of osteogenesis was criticized when it became apparent that new bone formation could not be considered the attribute of osteoblasts alone Barth (1893) concluded from carefully conducted experiments that all elements of transplanted bone die and are slowly replaced from adjacent bone producing tissue. Gallie (1914) performed a series of experiments on dogs, using a wedge of bone from the radius which he replaced in its original site to study autogenous grafts. He boiled the wedge before replacing it, covered the wedge graft with tinfoil on one of its cut surfaces and replaced the wedge taken from the dog's radius by one removed from a cat. He concluded that a bone graft merely supplies a medium for the invasion of bone cells from the host Phemister (1914) called this process creep-

ing substitution." It appeared difficult, however *to explain the rapidity of reproduction* of bone in large grafts if the source of the new bone was limited to host bone alone If Macewen's homogenous osteotomy wedges had merely served as a scaffolding *for the living bone of the distant* extremities of his patient's humerus could the shaft of the bone have been reproduced in the short time which had elapsed? The opinion of Leriche and Policard (1918) is that a graft can be the seat of osteogenesis only *if it is in contact with pre-existing bony* tissue which supplies a high local calcium supply causing a metaplasia of the surrounding young connective tissue osteoblasts are seen only after preosseous tissue *appears in the graft. When one observes* heterotopic ossification it would seem that survival of osteoblasts plays a minor role in regeneration for bone appears in areas such as nerves and arteries where osteoblasts are not found.

On the assumption that a bone graft serves merely as a framework to guide new bone originating from the host Gallie and Robertson (1919) used boiled bone in their experiments, however they obtained a *lower percentage of success than with the* fresh bone grafts. Orell (1937) reported the use of "os purum," or bone from which the organic elements had been partially removed chemically His findings seemed to indicate that slow revascularization and revitalization were due to the difficulty of resorbing and removing the coagulated cellular elements in the bony canals it appeared also that the removal of the organic elements diminished the stimulus for osteogenesis

To explain the stimulus which results in the invasion of the framework of the bone graft by new cells attempts were made to demonstrate an "organizing" substance in the graft which is responsible for osteogenesis After Robison's (1923) discovery of phosphatase it was predicted by some that phosphatase was directly related to ossification Huggins (1931) showed in dogs, *that bone forms from connective tissue in* the presence of growing bladder epithelium which contains large quantities of phosphatase. It has been suggested that alkaline phosphatase causes precipitation of calcium salts by the increase of phosphate ions, but this theory has not been proved.

Levander (1938) succeeded in producing new bone in rabbits by injecting alcoholic extract of normal bone or of callus into muscle. Annersten (1940) working with *rabbits obtained* formation of cartilage and bone in 1 of every 13 cases by the intramuscular injection of an alcoholic extract of bone or of callus. Annersten also obtained formation of cartilage and bone in a *proportion of 1 in 13 by injecting alcoholic* extracts of tendon when extracts of muscle were injected the proportion was slightly less—1 in 16 The results of Heinen's (1949) alcohol injection experiments seem to throw doubts upon the importance of these findings *Heinen produced bone in rabbit* muscle by the injection of alcohol alone

Bone grafts which remain unadulterated by chemical or physical influence may contain an enzyme like bone promoting sub*stance for which Lacroix (1949) suggested* the name "osteogenin" but there is no evidence to date of the existence of such a substance

Lacroix demonstrated that a fragment of tibial bone maintained for thirteen days in alcohol and inserted beneath the kidney capsule of a rabbit was undergoing resorption when examined three to seven months later but that there was also an accompanying osteoblastic activity in a layer of newly formed bone Upon repeating the experiment using bone boiled for 10 minutes in water the bone was found practically intact seven months later with little osteoblastic activity and no new bone formation it would thus seem that the capacity for osteogeneic activity is destroyed by the process of boiling Whether the stimulus for osteogenesis in such experi

ments originates from a growth promoting substance or from survival of osteoblasts or by both of these factors remains question able. That the ingrowing connective tissue cells of the host are induced to form bone by contact with the substance of the transplanted tissue seems more probable. Rather than limiting the activity to the usual in vasion of the transplant, the cells seem to acquire a potency to form bone Urist and McLean (1952) have termed this phenome non "bone formation by induction

There has been a tendency in recent years to attach little clinical importance to Ollier's original observations of the osteogenic properties of the periosteum Baentz ner (1921) Bull (1928) Levander (1939) Pollock and Henderson (1940) denied any osteogenic power to transplanted adult periosteum. The question that also arose was whether periosteum was osteogenic only if bone particles were attached to its under surface The fact that osteoblasts in the deepest stratum of the periosteum of grow ing animals were osteogenic was observed by Ollier as far back as 1858 his critics had alleged that he detached fragments of bony matter with the periosteum. He studied the periosteum and observed a gradual transition of structure from the superficial to the deep surface the deepest stratum was more cellular and osteoblasts were observed near the bone. Bonome (1885) con tended that transplanted periosteum main tains its osteogenic properties even though as he believed, the cells of the bone graft died. Levander concluded from his experi ments that the deep or cambial layer of the periosteum is *osteogenic in growing animals but that in older animals it tends to disappear* thus reducing the osteogenic properties of the periosteum Kolodny (1923) and Reiss (1924) had reached similar conclusions

Bisgard (1936) grafted periosteum alone, and periosteum and bone together into the anterior chamber of the eyes of rabbits. New bone formation occurred in both implants but was more abundant in the grafts of periosteum and bone Lacroix (1949) grafted adult tibial periosteum beneath the capsule of the kidney in rabbits and obtained new bone formation He noted that the periosteal implant contained neither the cambial layer characteristic of young periosteum nor bone fragments and that bone proliferation occurred only on the undersurface of the implant. This osteogenic potency of periosteum would seem to account for the spontaneous regeneration of resected segments of bone observed by White (1769) Syme (quoted by Keith 1919) Ollier (1867) and subsequently other sur geons (Kazanjian 1946) Syme resected a seg ment of the right and left radius in a young dog he also removed the periosteum on the right side and preserved the membrane on the left. Following sacrifice of the animal at the termination of six weeks, examination showed that the missing part of the left radius had been replaced *on the right*, where the periosteum had not been pre served, a gap still remained. Bertelsen (1944) reported that bone or cartilage was formed in four of twelve rabbits in which he had made intramuscular *injections* of an alcoholic extract of periosteum That bone forming properties of adult periosteum can be activated before transplanta tion by fracture of the underlying cortex has been demonstrated by Urist and Mc Lean (1952)

Studies by Wilson (1947) Reynolds and Oliver (1950) and Reynolds, Oliver and Ramsey (1951) seem to indicate that the major portion of the cells of the bone graft die Barth in 1893 had stated that the cel lular elements of the bone graft die In 1908 however he admitted that fresh au togenous bone grafts were capable of active new bone formation Axhausen (1909) Mayer and Wehner (1914) Phemister (1914) Brooks (1917) Haas (1922) Rhode (1925) Mowlem (1941) Abbott Schottstaedt Saun ders and Bost (1947) Ham and Gordon (1952) Urist and McLean (1952) all ex

pressed the opinion that osteogenic cells survive in fresh bone autografts. Ham and Gordon showed that cancellous chips form new bone when transplanted into muscle but that no new bone forms around chips which had been frozen and thawed three times. According to their interpretation this was due to the destruction of the osteoblasts. Campbell, Brower, Macfadden, Payne and Doherty (1953) have shown that in onlay split rib bone grafts, union of the cancellous portion of the graft to the host bed occurred in specimens which were removed two weeks after transplantation. They attributed this rapid union to the survival of osteogenic cells in the graft. It is possible that the cells of the Haversian canals, endosteum or periosteum may survive in bone grafts, for it has been shown that when an explant of embryonic bony tissue is placed in tissue culture, the cells of the Haversian canals or of the endosteum are seen to grow; these facts were established by Fell (1932), Caillard (1912) and Judet and Delaunay (1953). Heinen (1910) successfully transplanted the outgrowth from tissue cultures of bone into the anterior chamber of the eye. Pfeiffer (1948) transplanted samples of autogenous bone marrow with attached bone spicules or endosteum into the anterior chamber of the eye in mice and obtained new bone formation; only the reticular cells survived, and these were assumed to have the innate capacity to differentiate into osteoblasts. There would thus seem to be considerable circumstantial evidence in favor of osteogenic cell survival in fresh autogenous bone grafts. Growth on culture media has been limited to embryonic bone; the survival of osteoblasts awaits the successful culture of adult bone.

Holmstrand (1957) applied biophysical techniques, including microradiography, microroentgen ray diffraction and the polarizing microscope to the study of experimental bone grafts and bone implants in rabbits and dogs. Up to twenty-eight weeks following operation, autogenous cortical grafts were substituted more quickly than homogenous grafts, but at a later period following operation there was no observable difference between them. The resorption and subsequent substitution of different kinds of bone implants was found to be related to their respective crystallite sizes and the slowest resorption rate was manifested by calcined bone.

By micro-x ray diffraction, the organization of the new bone within fresh bone grafts was traced down to the molecular level. In the case of a cortical transplant sixty four weeks after operation, the results indicated that the substituting bone assumed the same organization as the graft, but with cancellous grafts the bone crystallites acquired an organization similar to the host bone, therefore indicating that cancellous grafts are to be preferred where quick restoration to the normal is desired.

Conclusions

In reviewing the research concerned with factors influencing osteogenesis and bone grafting, it is interesting to note that all the findings of early workers were at least correct in part. It has been shown that periosteum has osteogenic activity, as contended by Ollier; it is probable that osteoblasts survive under certain conditions, as Macewen maintained; and that the majority of bone graft cells die and are replaced by new cells, as originally observed by Barth.

Clinical Applications

A number of conclusions which have clinical applications stem from these studies.

1. The cells of the host are induced to form bone by contact with the transplanted tissue, which may contain an "organizer" or "osteogenin" which stimulates bone growth; physical or chemical injury of the bone graft therefore should be avoided to preserve this property. In addition, the soft tissues surrounding the transplant must be

healthy well vascularized, and capable of generating new osteogenic cells and capillaries

2 The survival of osteoblasts within the graft furnishes new centers of osteogenesis for its cellular repopulation The graft, therefore need not rely entirely upon metaplastic cells from the surrounding connective tissue nor upon cells from the host bone. Cancellous bone presents an extensive endosteal surface and numerous accompanying spaces which permit the extracellular fluid to permeate the graft nourishing the cells until the ingrowth of capillaries assures the blood supply Wide channels in the cancellous bone graft facilitate the penetration of new blood vessels and the accommodation of new bone.

3 Consolidation between grafted and host bone appears essential for permanent survival of the graft immobilization of the graft against the host bone and the absence of dead space are necessary to prevent injury of the young connective tissue growing into the transplant. Cellular invasion from the host bone reaches its maximum activity only when the surface of contact is wide and the adjustment precise, even though it is not essential nor even possible in surgery of the face to achieve the cabinet worker s precision advocated by Albee (1915)

Principles of Bone Grafting

Four conditions are necessary for successful bone grafting

1 The absence of infection Bone grafts should be transplanted into healed, non infected tissues the operation should be postponed until all evidence of infection has disappeared.

2. The provision of a healthy non-scarred vascular bed for the graft.

3 Subperiosteal contact between the graft and the adjacent bone must be established.

4 The graft must be immobilized to prevent movement due to lack of stabilization.

Types of Bone Grafts

The types of bone grafts most useful in the facial area are block grafts, osteoperiosteal grafts and chip grafts

Block Bone Grafts

A piece of bone containing both cortical and cancellous bone is shaped to fit a defect either before or after the bone has been removed from the donor site. The block graft is particularly useful for repair of a saddle nose for restoring continuity of the mandible, for filling skull defects and to restore the zygomatic prominence The ilium is commonly used as a source for most bone grafts.

Osteoperiosteal Grafts

These are bone chips or strips of bone with the periosteum attached. They are usually obtained from the flat medial surface of the tibia and are useful as onlays to cover a small defect between the bony ends in non united fractures of the mandible

Longacre and de Stefano (1956) have successfully employed split rib onlay bone grafts for large cranial and facial defects in children Because regeneration of bone in the ribs occurs this technique appears to be the choice one in children.

Chip Bone Grafts

Small pieces of cancellous bone are convenient for filling in surface bone defects and for interposing bone between separated bony fragments The best source of supply for chip grafts is the ilium but they may be procured from other cancellous bones. Chip grafts seem to be more resistant to infection regeneration occurs more rapidly than with other grafts because the small chips seem to favor the establishment of the vascular supply Chip bone grafts are also used to fill gaps beneath and between larger grafts of bone the chips are usually

packed at the junction between the bone graft and the surrounding area

The Ilium as a Donor Site

The portion of the iliac bone which serves as a donor site for bone grafts is composed of inner and outer tables and a layer of cancellous bone. The incision extends through the skin and periosteum to the crest of the ilium Just prior to the incision the skin is retracted upward by the assistant in order that the incision will be lateral and below the crest instead of over the crest following the removal of skin tension (Fig 477) the periosteum is then reflected and raised with a periosteal elevator Either a part of the crest the full thickness of the crest or the inner table are exposed (Fig 478) depending on the amount of bone required for the operation. The periosteum covering the outer surface of the ala is also raised, if the full thickness of the ala is required The inner table of the ilium and adherent cancellous bone can be removed when a wider surface of bone is required the periosteum is further elevated raising the iliacus muscle with the periosteum and thus exposing a portion of the iliac fossa By sectioning a portion of the crest vertically and splitting the crest horizontally between the vertical cuts, a section of the inner cortical table with its underlying cancellous bone may be separated and removed from the outer table (Fig 478C) This technique does not disturb the continuity of the crest and leaves no visible deformity The inner face of the ilium is exposed rather than the lateral aspect for the periosteum is raised with greater ease over the smooth inner surface which is roofed over by the iliacus muscle the lateral aspect of the bone is uneven serving as the area of insertion for gluteal muscles.

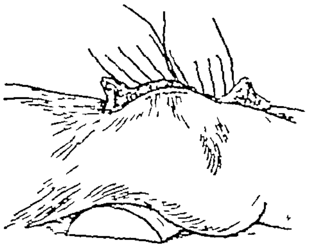

Fig 477 Exposure of the crest of the ilium for bone graft

A The patient's hip is elevated by a sandbag to make the iliac crest prominent. The assistant presses a gauze pad against the skin just below the crest of the ilium and pulls the skin over the crest

B The skin incision lies lateral to the crest of the ilium

The technique advocated by Robertson and Baron (1946) can be employed when a greater amount of bone is required in this technique the bone is sectioned below the crest of the ilium reflecting the crest upward thus preserving the origin of the abdominal muscles. Cancellous bone is removed from the center of the bone after separation of the cortical surfaces, and the crest is then replaced in its original position cancellous chips can be removed with a gouge A similar technique may be employed in children the intermediary cartilage which rims the crest must not be dis-

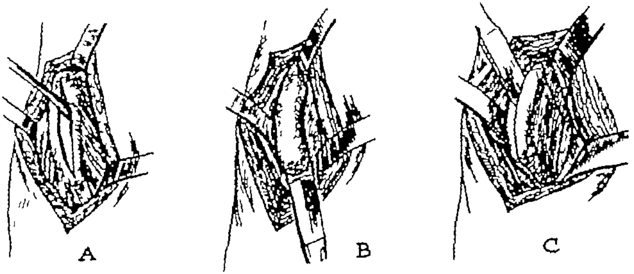

Fig 478. Removal of bone from the ilium
A. The periosteum has been incised and is being raised by an elevator
B. Resection of bone from the crest.
C. Resection of bone from the inner table.

turbed The cartilaginous portion of the crest is incised along its junction with the body of the bone and raised upward and medially the cartilage is not separated from the muscles of the trunk by this method and the major part of the blood supply is preserved.

In our series of bone grafts removed from the ilium we found that patients experienced more discomfort and difficulty in early ambulation when the full thickness of the ala was removed than when the outer table of the ilium was preserved this inconvenience may be the result of extensive stripping on the lateral surface of the ilium to obtain wide exposure or the resultant weakening of the attachments of the gluteal musculature particularly the gluteus medius and minimus, thus producing the so-called "gluteus gait, a persistent type of dragging limp When closing the wound care should be exercised to obtain accurate apposition of the periosteal surface from which the abdominal and gluteal muscles arise

An unusual complication can occur following the removal of the entire thickness of the anterior superior iliac spine. The attachment of the tensor fasciae femoris is recessed and the tendon slips over the trochanter at the point where it normally crosses the greater trochanter producing a clicking sound when the patient walks The entire thickness of the anterosuperior iliac spine need not be removed one-half of the thickness usually suffices.

Oldfield (1945) reported a sliding hernia of the cecum after massive removal of the ilium.

Temporary hypoesthesia of the thigh has been observed following removal of bone from the inner table of the ilium An anatomical explanation of this phenomenon is trauma to the lateral cutaneous nerve of the thigh due to retraction of the iliacus muscle in the exposure of the fossa it will be recalled that the nerve crosses the iliacus muscle in its passage toward the femoral triangle

Cancellous bone bleeds readily and hematoma formation is common particularly if the inner table of the bone has been exposed for a dead space remains between the bone and the detached iliacus muscle. Gelfoam soaked in thrombin solution or bone wax may be rubbed into the bleeding cancellous bone hemorrhage from a spurting vessel is arrested by crushing the bone around the vessel If the full thickness of the ala is removed the dead space can be

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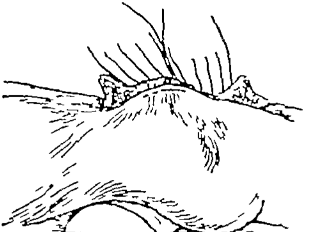

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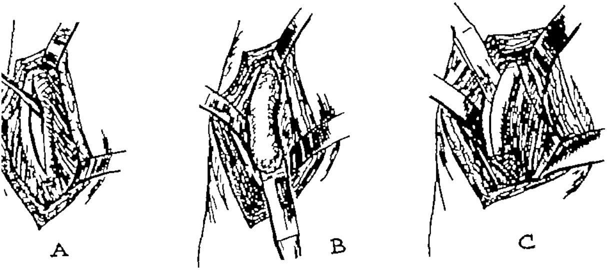

Fig 478. Removal of bone from the ilium
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eliminated by suturing the iliacus muscle to the glutei as advised by Dingman (1950) It is our practice after exposure of the inner table to leave a drain for a period of twenty four hours to evacuate accumulated blood The drain is placed in such a way that it may be removed on the day following operation without displacing the entire dressing Early ambulation reduces the period of discomfort and disability

The Tibia as a Donor Site

The tibia is exposed by making an incision medial to the crest from the tuberosity downward. Incisions directly over the crest of the tibia should be avoided for the healing of such wounds is a slow process. The anterior tibial muscles are then separated from the lateral side of the bone After adequate exposure an incision is made through the periosteum and the desired size and

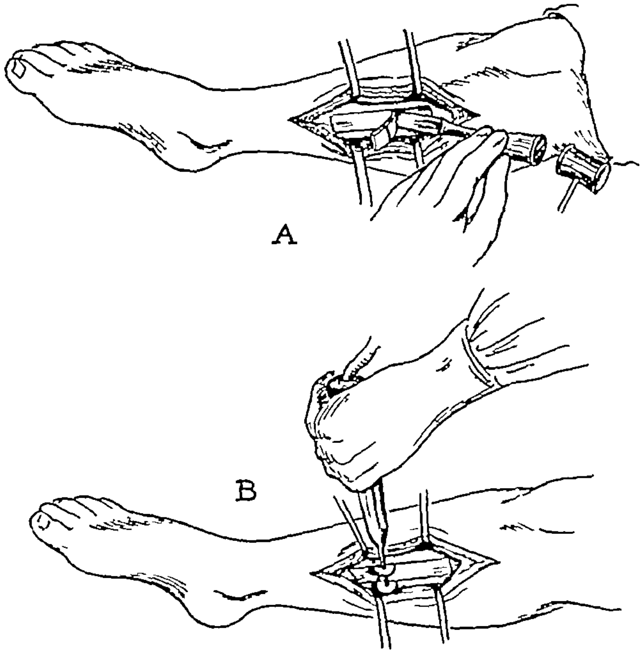

Fig. 479 Removal of a bone graft from the tibia

A Bone removed with osteotome

B Bone removed with parallel circular electrically-driven saw

shape of the graft is then outlined. Broad sharp osteotomes or circular motor-driven saws are used (Fig 479) Tibial bone is brittle in some adults and may break into fragments. The pieces, however remain attached to the periosteum and can be utilized as a single graft such brittle bone should be cut with the circular saw

Cortical bone is preferred for stability and cancellous bone for osteogenesis The cortex of the tibia is dense and resists penetration by new blood vessels Its use is contraindicated when rapid healing is essential for example, in restoring the continuity of the mandible.

The anterior crest is the strongest part of the tibia Removal of a small section of the crest or an excessively large or deep graft from the medial surface of the tibia has been known to weaken the bone resulting in fracture.

The Bone Bank in Plastic Surgery

The bone is placed in a sterile screw top container which is inserted into a larger container and then stored in a freezing unit at a temperature of $-20°$ F or at lower temperature. Bone grafts have been preserved in this manner for more than a year and successfully utilized as transplants The bone supply is obtained from excess bone removed during bone graft operations bone can also be obtained from amputated limbs osteotomies and rib resections The bone is stripped of soft tissue before storing In multiple stage procedures requiring bone grafts, the bone removed at the initial operation is preserved for future use

The utilization of homogenous bone readily available in the bone bank is often advantageous For example, when bone is required for filling small defects, the removal of a bone graft causes subsequent pain or discomfort and some patients object to the added procedure or a small bone graft may be required during the course of a reconstructive operation for which bone grafting was not anticipated

Inclan (1942) Bush (1947) and Wilson (1951) used refrigeration as a means of preservation Deep-freeze storage is now commonly used for preserving large quantities of bone removed in the course of operations, from amputated limbs or from recently deceased cadavers Kreuz, Hyatt, Turner and Bassett (1951) prepared bone grafts by freeze-drying for indefinite preservation and greater ease in transportation Bone heterografts from horses calves and pigs have also been used to simplify the problem of a ready and adequate supply of available bone (Judet Judet Lagrange and Dunoyer (1952)

Early reports of the use of bone banks and histologic studies of the comparative healing capacities of autogenous and homogenous bone grafts seemed to indicate a slower initial healing process and a lesser cellular activity in homografts. The microscopic picture of autografts and homografts however presented a similar appearance after a period varying from ten to twelve weeks (Wilson 1951 Reynolds and Oliver 1950)

More recent studies indicate a higher percentage of growth in autogenous bone than in preserved homogenous bone. Haas reported that only autogenous bone showed evidences of healing following the transplantation of fractured bone into muscle. Mosiman (1951) implanted a number of different bone fragments in the anterior chamber of the eyes of guinea pigs he used autogenous fragments from the fibula and also acetone fixed deep frozen boiled and Merthiolate preserved bone. Ninety-three *per cent* of the fresh autogenous bone grafts showed evidences of bone growth two weeks after implantation whereas the implants of dead bone showed no growth Bosworth Wright Fielding and Goodrich (1953) in spinal fusion operations for tuberculosis, *noted a non-consolidation* rate which was three times higher in cases grafted with refrigerated homogenous bone, than in those which were autografted. Reynolds (1953)

in discussing these findings stated that the use of homogenous bone had been discontinued in spinal fusion cases in his clinic except those in which the removal of autogenous bone was not indicated. Campbell Brower Macfadden Payne and Doherty (1953) in experiments using split rib grafts in dogs, found osteogenic activity only in fresh autogenous grafts. Ray Degge Cloyd and Moones (1952) found that fragments of embryonic bone which were frozen at −18 C. for twenty four hours, and were then transplanted to the anterior chamber of the eye of adult rats showed endochondral ossification autogenous adult cancellous and cortical bone treated similarly failed to survive Kiehn Cebul Berg Cutentag and Clover (1952) studying the vascularization of experimental bone grafts by means of radioactive phosphorus, found that autogenous bone showed a higher degree of penetration of P^{32} than homogenous bone. Concomitant studies of the vascularization of bone fragments placed in an Algyre chamber indicated that autogenous bone became vascularized more rapidly

In evaluating the respective merits of autogenous and homogenous bone the advantages of the bone bank for reconstructive surgery of large defects of the extremities and of various orthopedic conditions is obvious for a sufficient amount of bone is thus made available in addition secondary defects due to removal of bone from donor areas are avoided The choice of autogenous or homogenous bone depends largely on the type of surgical repair Bone grafting to bridge a gap between two ends of bone differs from the application of the onlay bone graft to restore contour deformity or to consolidate a non united fracture In the latter instance the wide bony surface of contact enables the success of grafts even when such substances as *boiled* cadaver bone (Lloyd Roberts, 1952) or heterografts (Judet Judet Lagrange and Dunover 1952) are used Judet and his coworkers basing their opinion upon a series of 160 cases of heterografts in humans w[illegible] convinced that heterografts are success[illegible] only when a wide surface of contact c[illegible] be obtained with the host bone.

A rising opinion favors the use of *fr*[illegible] autogenous bone grafts rather than ot[illegible] types of grafts. The substitution process [illegible] bone grafts is progressive but occurs w[illegible] gradually subsiding impetus the m[illegible] rapid the fixation of the graft the earl[illegible] its vascularization and cellular replaceme[illegible] Watson Jones (1953) in *expressing his pr*[illegible] erence for fresh autografts, stated that [illegible] favored a graft with bone cells which wou[illegible] "fight for him" An extensive review [illegible] 3101 homografts by Frantz Reynolds a[illegible] Lipscomb (1953) concludes that bank bo[illegible] cannot entirely replace autogenous bo[illegible] for grafting purposes although such bo[illegible] can be used successfully in well-select[illegible] cases complications are fewer and t[illegible] chances of success greater if frozen ba[illegible] bone is used rather than Merthiolate ba[illegible] bone

Bone Grafts for Facial Defects

As recently as 1916 when bone graft[illegible] of the mandible was referred to at all [illegible] was merely mentioned for the sake of a[illegible] demic completeness when papers were p[illegible] sented at the Royal Society of Medici[illegible] (Cole and Bubb 1919) The use of bone [illegible] the repair of skeletal defects of the fa[illegible] became an accepted method for the tre[illegible] ment of non-united mandibular fractu[illegible] during World War I

A brief resume of the history of bo[illegible] grafts for use in facial defects includes t[illegible] works of Delageniere (1916 1917) who e[illegible] ployed osteoperiosteal grafts from the tib[illegible] Lindemann (1916) who employed the cr[illegible] of the ilium and Gillies (1920) who e[illegible] dorsed the method of Lindemann Imbe[illegible] *and Real (1916) Lebedinsky and Vaenp*[illegible] (1918) McWilliams (1917) Ivy (1918) W[illegible] dron and Risdon (1919) Blair (1920) a[illegible] others established bone grafting of the ma[illegible] dible as an accepted technique Ivy (19[illegible]

published an excellent review of the history of bone grafting for the restoration of mandibular defects.

Skull defects were repaired by bone grafts either from the outer table of the skull adjacent to the defect, from the tibia or the ilium (Delagenière 1916 Gulecke, 1917 Lexer 1931 Grant and Norcross, 1939 Kazanjian and Converse 1940) Bone was also used as a nasal implant as early as 1911 by Carter (1911) Mowlem (1941) considered this type of transplant the most satisfactory for the treatment of saddle deformity of the nose.

During World War II bone grafts for surgery of the face were used extensively Mowlem (1944) simplified the technique by using cancellous chip bone grafts a technique which had been employed previously by orthopedic surgeons for filling bone cavities The ilium is now generally accepted as the donor site of choice for such bone grafts

Histological Examination of Bone Graft Biopsies

Biopsies of previously implanted bone grafts were obtained in 6 cases in which bone had been added to a previous graft, or where an overlying scar had been repaired (Converse and Campbell, 1954) at periods of three to six months after bone grafting The gross appearance of the grafts as seen in these biopsies differs from that of the host bone, appearing more porous The histological picture of the biopsied grafts (Fig 480) is similar to that described by Wilson (1951) Reynolds Oliver and Ramsey (1951) and others.

Microscopic studies indicate that with the ingrowth of capillaries, the graft is the seat of a dual process of destruction and reconstruction and of parallel osteoclastic and osteoblastic activity which extends over a varying period after transplantation. Active absorption of the dead trabeculae occurs simultaneously with an invasion of fibroblasts and blood vessels and osteoid tissue which appears to develop from the periphery of the transplant, and penetrates the interior of the graft (Fig 480) Adjacent to the trabeculae undergoing absorption by osteoclasts are areas where numerous osteoblasts are present, and newly formed bone with osteocytes is replacing the dead bone by creeping substitution (Fig 480) the graft thus seems to serve as a scaffolding for the new bone A new cortex is formed on the surface of the transplanted cancellous bone graft as observed by Mowlem (1941) this is clearly seen in roentgenograms eight to twelve weeks after transplantation. Remineralization of the graft is a slow process the graft appears less dense on x ray examination than the host bone in the early stages it assumes its usual roentgenological picture following the deposition of calcium salts.

Autogenous versus Homogenous Bone Grafts

In testing the degree of fixation of bone grafts to host bone fresh autogenous onlay bone grafts over the mental symphysis consisting mostly of cancellous bone became attached in seven to ten days homografts required a longer period. When fresh autogenous bone grafts were employed the consolidation period varied between four and six weeks in full thickness defects of the mandible a much longer period of time elapsed before consolidation occurred when homografts were employed. In one graft of refrigerated mandibular cadaver bone immobilization by splinting was required for a period of four months before consolidation was completed

Cancellous versus Cortical Bone Grafts

Rapid consolidation is necessary in facial bone grafts because prolonged immobilization is not as feasible in the face as, for example, in the extremities The progressively subsiding impetus of osteogenesis requires rapid consolidation this is best achieved by the use of autogenous cancel

FIG. 400 Histological aspect of a three-month-old autogenous bone graft to restore chin contour
A. Photomicrograph showing in (B) an area of new bone formation with osteoblasts and in (C) an area of dead bone being resorbed. Osteoclasts are present.
B Drawing Enlargement of Area B in A illustrating new bone formation with osteoblasts.
C Drawing Enlargement of C in A showing dead bone and osteoclasts
(From J M Converse and R M Campbell, S Clin of North America 34 3 1954)

lous grafts The free surfaces of cancellous bone are more readily exposed to tissue fluid nourishment than cortical bone The cellular elements of bone and the organic intercellular substance in the early stages following transplantation are nourished by extracellular fluid before the ingrowth of new capillaries occurs a process which usually requires a number of days The nutrient *fluids may penetrate the grafted bone* in the manner described by Ham (1952) as "nutrition beyond the capillaries." Tissue fluids may diffuse through the minute canaliculi of bone and it seems probable that tissue fluids serve as a means for the diffusion of nutritional and waste substances, a process similar to the so-called plasmatic circulation of skin grafts (see Chapter 15)

A high percentage of success is obtained when bone grafts are of the onlay type placed under the periosteum with wide *bony surface contact with the host bone* This condition is not present however in *all cases In nasal bone grafts the implant* is in contact with the host bone only at the

upper portion of the graft. In a case of reconstruction of the maxilla (see Figs. 605 and 610 Chapter 21) bony contact between the grafts and the host bone could be established only in two small areas one over the frontal process of the maxilla and the other at the anterior part of the zygomatic process of the temporal bone successful consolidation of the bone grafts ensued.

The surface of contact of the bone graft with the host bone is relatively small in full thickness mandibular defects In all such types of defects, when a wide surface of contact with the host bone is not feasible, fresh autogenous bone is indicated because of its higher osteogenic potency

Homogenous bank bone however proved useful for small defects when bank bone was required during an operation when no previous plans for a graft had been anticipated. Bank bone is also useful to supplement autogenous bone when an insufficient amount of bone has been removed. Excess autogenous bone may be stored for future use when stage procedures are necessary thus avoiding the repeated removal of iliac bone grafts.

Relatively small quantities of bone are required in grafts of the facial area and it is generally possible to obtain enough bone from the patient's ilium. We have never encountered a patient with a facial deformity who objected to removal of bone from the ilium. Fresh autogenous cancellous bone remains the material of choice.

20

DEFORMITIES OF THE UPPER PORTION OF THE FACE AND OF THE SCALP

The upper third of the face is located above the level of a horizontal line passing through nasion and consists of the forehead the eyebrows and the supraorbital arches, which are covered by muscles of expression principally the frontalis. Because of the intimate relationship of the forehead region and the scalp, and the frequency of associated surgical conditions, deformities of the scalp are included in this chapter

SCALP DEFORMITIES

Anatomical Considerations

The skin of the scalp is thick in the occipital area and thinner in the frontal temporal and mastoid regions. The scalp adheres to the superficial fascia and is firmly attached to the underlying occipitofrontalis muscle or epicranius. The galea aponeurotica is a dense fibrous tendinous structure *between the frontalis muscle anteriorly and* the occipitalis muscle posteriorly The occipitofrontalis is loosely connected to the pericranium by subaponeurotic areolar tissue a layer composed of a network of loose *areolar tissue containing fat A wound is en*larged by the pull of the aponeurosis when the galea is cut transversely a gaping wound causes an apparent increase in the size of the defect because the frontalis and occipitalis muscles draw the galea aponeurotica tightly over the cranium In plastic repair of scalp defects after excising a scarred area of the scalp and raising a flap from the adjacent area the flap may appear too small for the size of the defect unless the surgeon is aware that the gaping is due to the pull on the galea of the occipitofrontalis muscle In contradistinction to the gaping of transverse wounds of the galea little separation of the wound edges occurs after sagittal section.

The superficial fascia binds the scalp tightly to the underlying musculature contains superficial blood vessels and nerves which extend through the fascia and dense fibrous bands which extend between lobules of fat this fascia continues laterally over the temporal fascia where it is more loosely attached

The skin of the scalp is thicker than the skin elsewhere in the head and neck. Many hair follicles extend through the skin deep into the fat of the superficial fascia (Fig 181). This anatomical relationship accounts for resulting failure when an attempt is made to replace an avulsed *portion of the* scalp as a free graft the thick layer of fat prevents the growth of blood vessels into the transplanted scalp.

The pericranium or external periosteum *is a thin fibrous membrane containing* blood vessels and is loosely attached to the cortex of the outer table of the skull except at the suture lines where it is fairly adherent

Arterial blood to the superficial layers of the scalp is supplied by vessels entering the scalp at its periphery (Fig 182) The supratrochlear supraorbital arteries and terminal branches of the superficial temporal artery supply the forehead anterior part of the

FIG. 481 Photomicrograph of a cross-section of scalp showing the hair follicles in the fat of the superficial fascia.

(V H Kazanjian and R. C. Webster Plast. & Reconstruct. Surg., 1:360 1946)

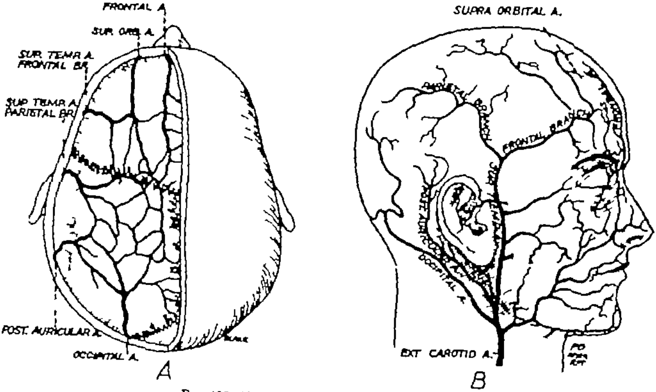

FIG 482. The arterial blood supply of the scalp

scalp and part of the temporal region. The parietal branch of the superficial temporal artery supplies the part of the scalp extending from above the ear to the vertex. The posterior auricular and occipital arteries nourish the portion of the scalp posterior to the ear and in the occipital region

A consideration of the vascular supply of

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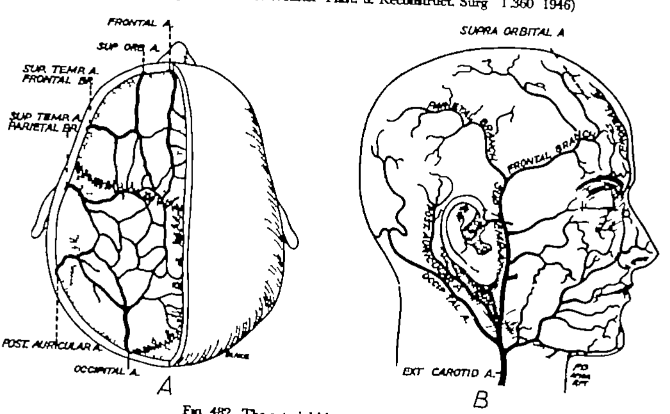

FIG 482 The arterial blood supply of the scalp

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A consideration of the vascular supply of

the scalp is essential in selecting the flaps to be used in the repair of defects and in deciding the direction of scalp incisions. The vessels which supply the scalp are peripheral and are not branches of perforating vessels as in other areas of the body. It is usually possible to design the flap to provide a vascular pedicle. Because of the abundant blood supply of the scalp, large flaps can be shifted on relatively small pedicles if the pedicle includes an arterial venous bundle. In the rare instance when delay of the scalp flap is necessary because of the unusual size of the flap, or because the flap must be designed in a retrograde manner in relation to the blood supply, a simple incision through the scalp and the galea aponeurotica without undercutting the flap is adequate. The simple outline delay is satisfactory because of the absence of perforating vessels in the scalp.

Because of the vascular distribution to the scalp, care should be exercised when placing operative incisions, especially in relation to pre-existing operative or traumatic scars. When an incision to establish the outline of a flap crosses the line of the scar, the distal portion of the flap becomes necrosed due to inadequate blood supply (Fig. 483).

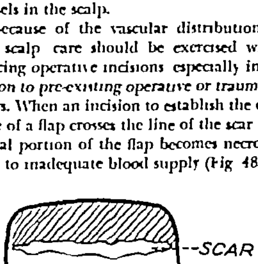


Fig. 483. The distal portion of the flap is poorly vascularized because of the presence of a transverse scar and may become necrosed.

TRAUMATIC AVULSION OF THE SCALP

Partial or total scalping has occurred in transportation accidents and occasionally in factories as the result of the entanglement of the hair of female workers in machinery. The tensile strength of the hair and its firm attachment result in the ripping away of the scalp from the cranium. The *line of tearing usually begins in the frontal* area, where the skin of the scalp is thinner; the prominent supraobrital ridges appear to cut through the thin skin of the upper lids when the scalp is torn from the cranium (Fig. 481). The line of cleavage usually occurs through the loose areolar tissue deep to the occipitofrontalis muscle. The periosteum *often remains intact but may either* be avulsed with the scalp or torn, remaining attached as a flap. The skull is rarely fractured. The auricles may also be involved and are sometimes removed with the scalp.

Surgical Management

Bleeding is usually profuse in such traumatic avulsions and transfusions are indicated. The wound is cleansed and debrided under general anesthesia when the patient's condition permits surgery. As little as possible of the partially detached scalp is removed, for the scalp is so vascular that most or all of it can usually be preserved, even when the pedicles of the torn scalp flaps are small. *If portions of periosteum have* been lifted as flaps, they should be preserved and reattached with sutures.

Treatment when the Periosteum is Intact

Treatment depends upon whether the periosteum is intact or destroyed. The blood supply of the periosteum is sufficient to sustain skin grafts. It is not necessary to await granulation, for the opportunity to place a graft upon a surgically clean field slips *away with the hours.* Thick split thickness grafts, cut with the dermatome, provide a means of repair when the periosteum is intact; the functional result is better than that

A D B E C F

Fig 484 Traumatic avulsion of the scalp A. Appearance of patient one day after total avulsion of the scalp caused by the entanglement of the patient's hair in machinery The pericranium is intact. B. Dermatome graft applied to the frontal area. The remaining raw area is covered with skin grafts in the same operation. C. Shows a second graft applied. D Appearance of patient at time of first postoperative dressing one week later E. Another case. This photograph demonstrates the futility of attempting replacement of the avulsed scalp. One week after replacement the scalp appears necrotic through deficient blood supply F Five days later the scalp has become gangrenous.

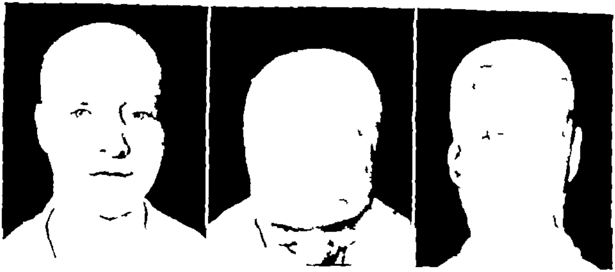


Fig 485 Successful covering of the denuded pericranium by split thickness grafts in patient shown in Figure 481 A to D

Fig 486 Patient shown in Figure 481 A to D and 485 wearing transformation The eyebrows were not restored the patient being able to use an eyebrow pencil effectively

obtained by the use of the thinner Thiersch graft Split thickness grafts are sutured to the edges of the remaining scalp and to each other (Fig 481) or if time is a factor because of the patient's condition the grafts are applied to the wound with overlapping edges. A satisfactory skin covering is thus obtained (Figs. 485 486)

Attempts to replace the completely detached scalp have been unsuccessful (Kazanjian and Webster 1947) (Fig 481E F). The galea and the fat must be removed to reattach the scalp as a full thickness graft when the fat is removed the original purpose of the procedure is defeated for many of the hair follicles plunge deeply into the fat and are destroyed when the fat is excised

Treatment when the Periosteum is Destroyed

Skin grafts cannot be expected to supply a permanent coverage over the denuded skull when the periosteum has been avulsed The split thickness graft may be applied to the denuded bone although temporary coverage is thus obtained it is rarely lasting Breakdown of the graft and chronic ulceration result in exposure of the bone requiring secondary repair of the area The exposed bone can occasionally be covered by a flap from the adjoining tissue immediately after the accident Denuded bone deprived

of its blood supply is destined to sequestration When the outer table is exfoliated however, the bone becomes covered with granulation tissue and at this stage, a thick split thickness skin graft will provide a satisfactory permanent covering

The procedure of choice in order to obtain a bed of granulation tissue over the bone for successful skin grafting is to expose the diploe the vascular area between the tables of the cranium. The method usually employed in the past consisted of boring holes in the outer table with trephines until bleeding points were found. This is a slow procedure, for granulations growing out of the holes require time to unite and to completely cover the devitalized bone remaining in the intervening space.

A simpler and more satisfactory method is to remove a portion of the outer cortex with an osteotome until multiple bleeding points appear In one week, or slightly longer the granulations which spring from these numerous bleeding points coalesce and subsequently produce a fine carpet of granulations receptive to skin grafting The skin grafting operation should be postponed until the bed of granulations is well-developed when the thicker split thickness grafts are to be used

Complications

Scar contracture following inadequate early treatment is likely to involve the eyelids, particularly the upper eyelids (Fig 487) Cases have been reported in which enucleation of the globe for panophthalmitis has been indicated after extreme retraction and eversion of the lids and corneal ulceration Damage to the globe due to exposure can be anticipated when the skin of the eyebrows and upper eyelids has been avulsed this serious complication can be prevented by grafting the area as early as possible.

Scar epithelium is thin and tightly stretched in areas which have been inadequately treated in the early period following trauma. The scar lines may break down at the areas of junction of the skin grafts Because return of sensation is delayed for many

A  B

Fig 487

A Extreme ectropion following avulsion of the scalp which had occurred twenty-six years prior to admission.

B. Profile view Note the chronic ulcerated areas with exposed bone.

FIG. 488 Repair of scalp defect by distant flap

A. Photograph showing the extent of the scarred area and the size of the ulcerated carcinomatous portion

B. View showing the large tubed pedicle flap extending from the back to the right breast

C. Photograph showing the tubed pedicle attached to the forearm and applied to the scalp defect left after excision of the lesion.

D, E, F Three photographs showing the appearance of the patient at discharge

years in some cases and never completely returns in others the scarred areas are particularly subject to trauma. The blood supply is often inadequate in such cases and slowly healing recurrent ulcerations are common

Old ulcerative lesions in avascular scars have also been known to undergo degenerative changes leading to carcinoma. It is necessary in such cases to remove the malignant tissue as well as the underlying bone. The

FIG 489 A, B. Photographs showing large defect of the scalp following burns. It was possible to close the entire bald area in three operations.

C, D Photographs a year later than in the views shown in A and B.

repair may be accomplished by a distant tubed pedicled flap employing the patient's wrist as a carrier (Fig 488) The detached end of the tubed flap must be sutured to an adjacent well vascularized area If the scalp surrounding the defect is not suitable the flap is attached in the temporal or parietal region within the vicinity of the terminal blood vessels of the adjacent portions of the scalp In a later stage after one pedicle of the flap has become satisfactorily vascularized the remainder of the flap is opened and applied over the bony defect.

Recurrent ulcerations resulting from the stretching of scar epithelium should be excised and the area resurfaced by a flap of skin or scalp. Ulcerations, following skin grafting may occur between the graft patches or in the middle of the graft. The grafts appear to be stretched excessively and attached tightly to the underlying bone Treatment consists of additional skin grafting to relieve tension and if necessary excision of the ulcerated areas and replacement of tissue by means of a local or a distant flap

Isolated scalp defects in which hair follicles are destroyed leaving patches of scarred bald areas, are common in burn cases (Fig 489) The defect is concealed if the surrounding hair is abundant. If required, the defect may be excised and repaired by a local scalp flap (see Figs. 493 to 496)

SURGICAL CLOSURE OF SCALP DEFECTS

The need for adequate closure of scalp defects received emphasis during the First World War (Cushing 1918). Such defects may involve the soft tissues only or may include cranial bones. Denudation of the skull may be followed by ischemic necrosis, osteitis and sequestration of bone exposure of the brain may result in herniation. An adequate soft tissue covering is an essential requirement before attempting reconstruction of bony defects of the skull the continuity of the hair-bearing scalp is also required for cosmetic reasons.

In scalp defects complicated by loss of a portion of the cranium a skin graft may be

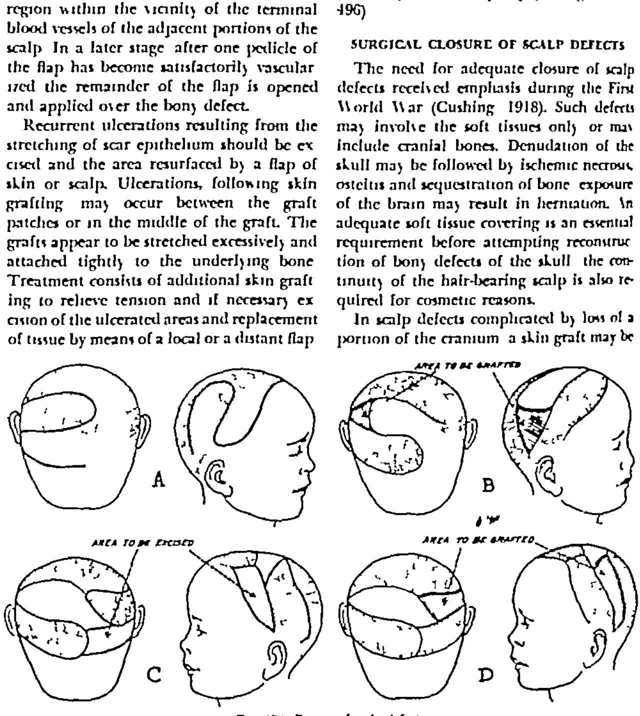


Fig 490 Repair of scalp defect

A, B. In the first operation a large flap from the right occipital region was transposed to the temporal region and the donor area was closed by shifting the skin of the bald area and applying a skin graft

C, D In the next operation another rectangular flap of hairbearing skin was transposed from the left occipitoparietal region

applied over the exposed brain as an emergency measure to prevent herniation or over the exposed cranial bone after an area of scalp has been avulsed or destroyed As stated earlier in the text, when applied over pericranium free split thickness skin grafts are usually successful the survival of skin grafts is less certain when placed over bone stripped of periosteum Whereas in extensive scalp avulsion skin grafting is the procedure of choice in small scalp defects it presents two inconveniences (1) the skin graft provides a thin covering cosmetically undesirable and (2) the skin graft is unsuitable if the repair of an underlying cranial defect is required Local flaps of scalp tissue are preferable when possible.

The local scalp flap is raised by establishing a plane of cleavage through the loose connective tissue between the cranial periosteum and the galea aponeurotica After the flap is transposed into the defect, a split thickness graft covers the secondary defect produced by the mobilization of the flap

Fig 491 Repair of scalp defect

A, B, C. Photographs of patient who had lost the hair of the greater part of the scalp from burns.

D E. The hairless area has been transferred to the parietal region where it is possible to conceal it by allowing the hair to grow long The technique employed is illustrated in Figure 490

if closure by direct approximation or by an additional adjacent flap is not feasible, tension is thus avoided and satisfactory healing occurs. The pericranium must be preserved when a scalp flap is raised, for the survival of a skin graft depends upon the presence of this structure.

Figure 490 illustrates the repair of a scalp defect. Two rectangular flaps of hair bearing scalp from the occipitoparietal region re-establish the hairline of the forehead. The defect is not reduced in size but is shifted to a less conspicuous area. The hair of the transplanted scalp flap is permitted to grow long enough to cover the posterior skin grafted area (Fig. 491). The photographs in Figures 489 and 491 exemplify the repair of scalp defects resulting from burns.

Large bipedicled flaps can be used to cover lateral parietal defects. An example of such a defect is shown in Figure 492. The excision of a malignant lesion in this case required removal of the skin, temporalis muscle and periosteum of the right temporal fossa. Previous to excision of the lesion, a large anteroposterior bipedicled flap was prepared under local anesthesia and delayed because of its length, the incisions extending through the galea without undermining the flap. The excision four weeks later the flap was raised and transposed over the defect, being applied directly to the denuded bone. Split

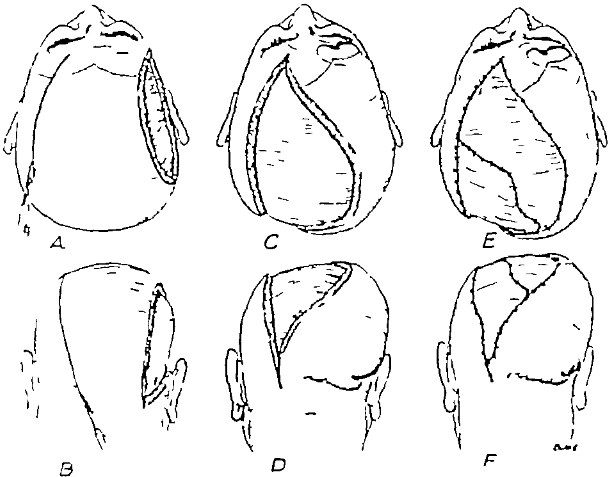


Fig. 492. Large transposed bipedicle scalp flap for closure of temporal defect.

A and B, Design of large bipedicled scalp flap.

B and C, Flap transposed over the defect.

D and F, Secondary defect covered by skin grafts applied over the pericranium.

(Figs. 489 to 491 and Fig. 492 from J. M. Converse: "Surgical Closure of Scalp Defects," in E. A. Kahn, R. C. Bassett, R. C. Schneider and E. C. Crosby: Correlative Neurosurgery. Charles C. Thomas [illegible])

thickness skin grafts were then placed on the pericranium of the secondary defect (Fig 492)

A rotation flap is usually employed for the closure of a triangular shaped defect Such a flap is designed in a circular fashion to distribute tissue tension An incision which follows the contour of the base of the triangular defect is extended over a wide semicircular area When this large flap is raised, it is rotated in such a manner as to close the defect without distorting the adjacent area (Figs 493 to 495) The large size of the flap permits greater equalization of tension A narrow pedicle may be used and greater mobility can be obtained when larger vessels, such as the branches of the superficial temporal artery and vein are included in the flap

Two flaps rotated in opposite directions are frequently employed to close large defects. The following case illustrates the use of such flaps when an area of the cranium is destroyed and the brain is exposed During World War II a pilot incurred an occipital defect approximately 10 cm. in diameter involving the scalp and the bone. In the course of a forced landing of the plane with the landing gear up during the Battle of the Bulge a propeller blade broke on striking the ground and passed through the windshield cleanly removing an area of his scalp and producing a depressed comminuted fracture of the occipital bone Previous treatment included debridement and unsuccessful attempts to close the wound. Successful treatment was finally achieved by two large rotation flaps (Fig 496) The secondary defects after shifting the scalp flaps, were covered with split thickness skin grafts over the pericranium. Later after returning to the United States, a tantalum plate was placed beneath the flaps to fill the bony defect. The patient had an uneventful recovery

Another example of the closure of a large occipital defect by two flaps rotated in opposite directions is shown in Figure 497

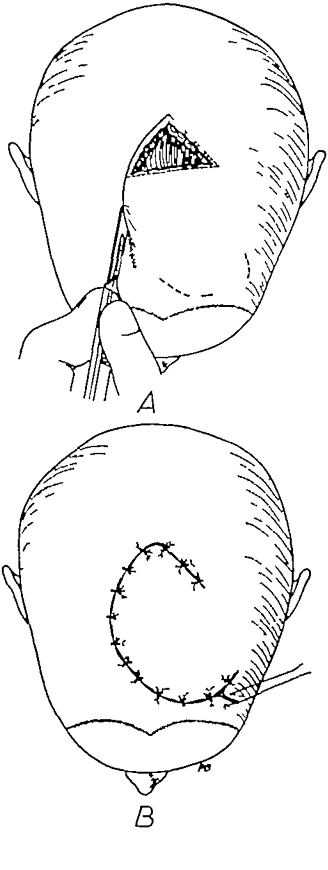


Fig 493 Swinging rotation flap closure of a scalp defect.

A. Design of rotation flap.

B. Rotation flap placed over defect closure of the secondary defect by the V Y method

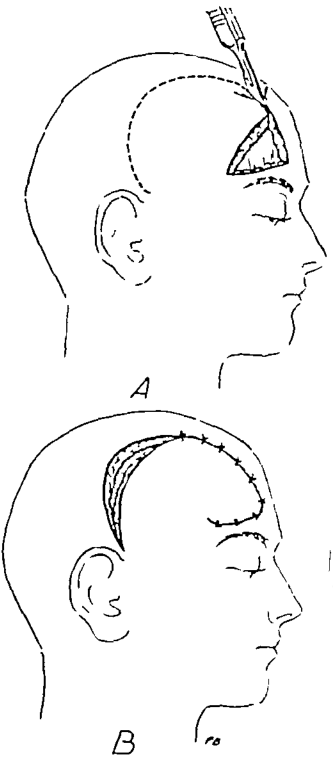


Fig 494 Swinging rotation flap including the superficial temporal vessels in the pedicle

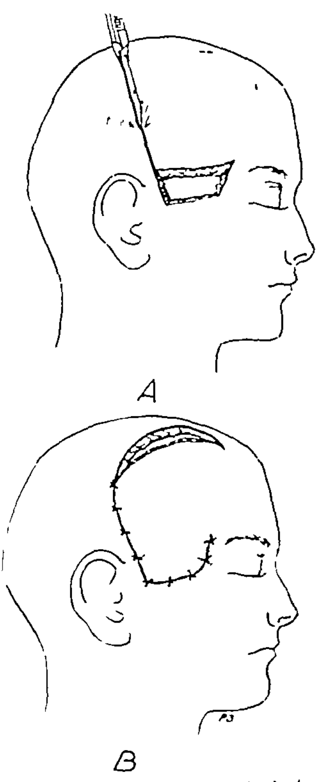


Fig 495 Retrograde rotation flap designed with broad pedicle This broad pedicle is necessary to insure the vascularization of the flap because the branches of the superficial temporal vessels are severed.

Flaps Transferred from Distant Areas

Distant pedicled flap repair is a necessary reconstructive procedure when local flaps cannot be employed or wh efect is too large because the sue is scarred and is unsuited over

the def d pedicled flap for ex ample sed from the abdominal wall la to the wrist and finally

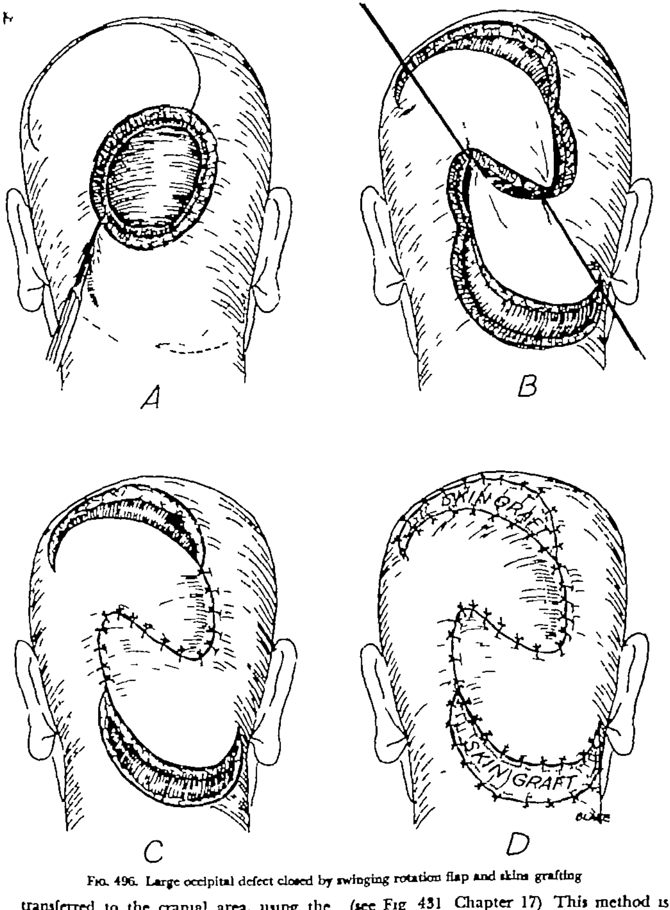


Fig. 496. Large occipital defect closed by swinging rotation flap and skin grafting

transferred to the cranial area, using the upper extremity as a carrier (Fig 498) Another technique of flap transplantation in large defects is the closed carried flap (see Fig 431 Chapter 17) This method is of particular value in repairing large cranial defects because a wide abdominal flap may be attached to the upper extremity and

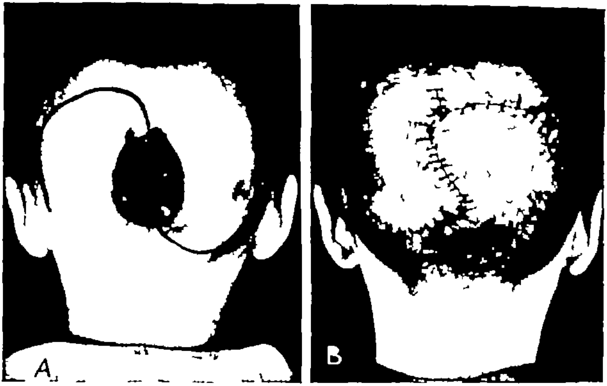


FIG 497 Example of defect closed by swinging rotation flaps

later transferred to the skull defect. The relative rapidity of the flap transfer when the upper extremity is used as a carrier compensates for the discomfort incurred by the patient during the immobilization of the upper extremity which is necessary to achieve approximation of the donor and recipient areas.

SOFT TISSUE DEFORMITIES OF THE FOREHEAD

Anatomical Considerations

The frontal bone forms the anterior portion of the cranial vault and the greater part of the floor of the anterior cranial fossa This large bone of the cranium also forms the supraorbital arches which constitute the upper limits of the orbital margins and the roof of the orbit. The frontal bone joins the nasal bones in the mid line and through the strong nasal spine lends support to the upper part of the nasal bones. The frontalis muscles, which are separated in the mid line lie over the periosteum of the frontal bone This gap between the two muscles is significant in surgery of the region Flaps from the mid line of the forehead may be removed down to the periosteum without interfering with the frontalis muscles located laterally to the mid line and inserted into the galea aponeurotica in the upper portion of the forehead The frontalis muscles are covered by thick skin which develops characteristic horizontal folds of expression Despite the fact that Langer s lines extend vertically in the forehead scars situated within or parallel to the horizontal folds of expression heal with less scarring than vertical scars.

The normal outline of the eyebrows and hairline should not be disturbed after careful primary suturing for the scars eventually become less visible Scars with uneven and elevated borders or which occupy a wide area should be excised If the frontalis muscle has been divided the scar tissue should be excised and the muscle sutured

When the surrounding skin of the forehead is unscarred an inconspicuous scar line is obtained by total excision of the scar tissue followed by undermining and careful approximation of the skin edges. The

FIG. 498. Technique of loosening scalp flaps by incisions through the galea aponeurotica

A. Flaps retracted around a defect due to resection of the frontal bone following osteomyelitis.

B. Criss-cross incisions through the galea and frontalis muscle to relieve tension and permit return of the flaps to their original position

direction of the scar whether vertical or horizontal does not seem to affect the quality of the repair

Skin Loss

Small defects in the skin of the forehead which remain after the removal of scar tissue are closed by approximation after extensive undermining if the wound is favorably located along the median line or in the frontal region. The surrounding tissues are stretched after undermining through the plane between the frontalis muscle or galea aponeurotica and pericranium raising the flap and making a number of vertical incisions through the frontalis muscle or the galea (Fig 498)

Deformities of the forehead characterized by patches of scars of various sizes require other methods of tissue replacement such as local flaps skin grafts or distant flaps, if the wound edges cannot be approximated after extensive undermining and incisions in the frontalis muscle and galea.

When the skin of the forehead below the hairline is not involved the scar tissue being located above the eyebrows flaps are transposed to cover the defect above the eyebrows, and a skin graft is placed in the secondary defect near or behind the hair line thus shifting the defect to a less conspicuous area (Fig 499)

A straight advancement flap may be uti

FIG. 499 (*Left*) Photograph showing conspicuous scar of the central portion of the forehead extending to the left temporal region.

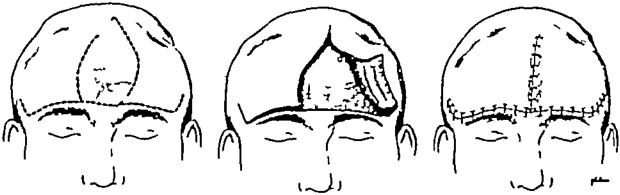
(*Center*) The entire scar was excised. A large flap from the right side of the forehead was brought down to cover the defect of the lower part of the forehead. The raw area near the hairline was covered with a post auricular full thickness free graft.

(*Right*) Photograph of completed case.

lized to advantage when the surrounding tissue is loose as in older individuals. The cutaneous structures are freed from the periosteum of the frontal bone and incisions are made through the galea and frontalis muscles, in order that the advancement may be achieved with minimum tension on the tissues (Figs. 500, 501)

A one-piece split thickness skin graft provides an excellent method of repair when most of the forehead skin must be replaced. The scar lines delimiting such a large graft area less obvious for they extend to the boundaries of the forehead. The graft becomes mobile over the underlying structures if the fibers of the frontalis muscle are preserved and elevation and wrinkling of the forehead skin continues in normal fashion.

In compound wounds of the frontal region with loss of soft tissue and bone cover



A B C

Fig. 500 Rotation flaps for closure of a defect of the forehead

A. Outline of flaps.
B. Vertical incisions are made through the frontalis muscle to permit stretching the flap
C. Approximation of the flaps.

(Figs. 500 and 501 from V. H. Kazanjian, Surg., Gynec. and Obst., 83:37, 1946)

Fig. 501 Photographs illustrating the closure of a forehead defect after excision of a nevus by the technique shown in Figure 500

FIG 502 *Emergency* closure of frontal defect with bipedicled temporal scalp flap The flap is nourished by the superficial temporal vessels on each side, thus permitting narrow pedicles. The scalp defect is temporarily skin-grafted

age of the dura may be obtained by means of a bipedicled temporal scalp flap as an emergency procedure (Fig 502)

It is not possible to use a simple procedure such as transposition of a local flap or a skin graft in extensive destruction of the forehead skin and scalp Flaps from distant donor areas such as the scapular region or the abdomen are indicated if a great deal of periosteum has been destroyed and sufficient healthy surrounding tissue is not available to permit the use of local flaps.

DEFORMITIES OF THE EYEBROWS

Repair of the Displaced Eyebrow

The displaced eyebrow is an obvious esthetic defect because of the contrast with the unaffected eyebrow Horizontal displacement often occurs between two portions of the eyebrow separated by a hairless scarred area Vertical displacement of the entire eyebrow or of one end usually upward is the result of the pull of a linear scar of the forehead Displacement of the eyebrow is facilitated because of the fact that the eyebrow is loosely bound to the supraorbital arch by connective tissue. Horizontal displacement is usually corrected by reassembling the displaced parts vertical displacement is repaired by Z plasty (Fig 503 504)

Reconstruction of the Eyebrow

The survival of hair follicles in free grafts of scalp depends upon the preservation of the fat layer in which the hair follicles are imbedded The presence of fat however acts as a barrier to the penetration of blood vessels through the deep surface of the graft which must rely upon revascularization through its lateral surfaces. The width of the graft is limited therefore to approximately 0.5 cm in order to assure revascularization and survival If

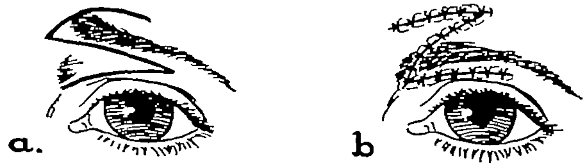


FIG 503 Correction of displaced eyebrow
A, B. Technique of correction of raised medial portion of the eyebrow by Z-flaps.

Fig 504
(*Left*) Photograph showing displacement of the left eyebrow
(*Right*) Photograph following correction by technique illustrated in Figure 505

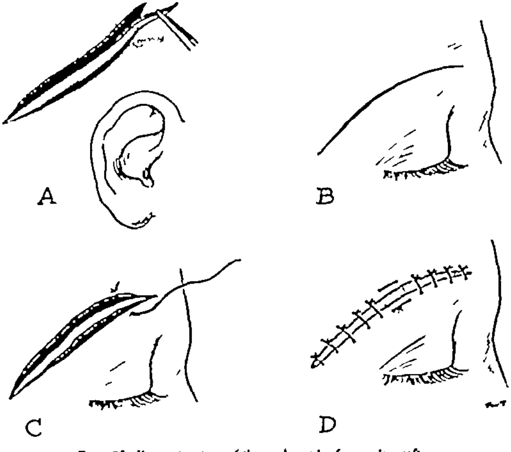


Fig 505 Reconstruction of the eyebrow by free scalp graft
A. Removal of strip of scalp from the temporal area
B. Incision made in the supraorbital area to receive the scalp transplant
C. Scalp graft placed in its bed Note method of suturing
D. *Scalp graft sutured in position The sutures are tied over the graft to provide fixation*

FIG 506

(*Left*) Loss of both eyebrows from burns.
(*Right*) The right eyebrow was restored by a free graft, and the left, by an artery island flap from the temporal region.

a wider graft is required, one of two procedures is followed In the first, two successive grafts of narrow dimensions are employed because the small size of each graft favors survival the second procedure employs a flap of hairbearing scalp

In preparing a site for the implantation of an eyebrow the supraorbital ridge serves as a guide and the eyebrow on the unaffected side as a model.

The Scalp Graft

Because the hairs of the eyebrows are directed obliquely and laterally a strip of scalp is removed in which the hairs are implanted in the same direction. A vertical strip may be removed from the temporal or mastoid regions (Figs. 505 506) The free graft of scalp should be thick the fat is not trimmed down to the base of the dermis as in the usual full thickness graft for the base of the hair follicles are implanted in the fat layer of the scalp and the survival of the graft is dependent upon the establishment of lateral vascularization Although survival is doubtful if the graft is more than 0.5 cm. in width grafts about 1 cm. in width may be successfully employed in children Two successive grafts are often required to construct an eyebrow of the desired size.

The new eyebrow is carefully attached in its supraorbital bed with the finest suture material and covered with a mildly compressive pressure dressing

After an approximate 2 week postoperative period of initial growth loss of hair usually occurs during the subsequent one or two months. Two or three months later however regrowth of hair is observed, the transplanted hairs often requiring periodic trimming In small grafts, in which adequate revascularization occurs early the period of hair loss followed by regrowth is not observed.

Artery Island Flap

When the forehead is otherwise intact, an eyebrow may be restored with an artery island flap a method which employs the transfer of a piece of scalp attached to an arteriovenous pedicle the posterior branches of the superficial temporal artery and vein. The location of these vessels is determined previous to operation by the elastic band test after the hair of the area has been shaved (Fig 507) The temporal vessels and the portion of the scalp to be used for the new eyebrow are outlined in ink (Fig 508*A*)

An incision is made over the vascular pedicle through the skin but not deep

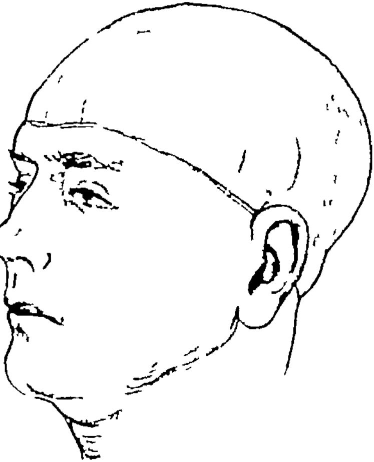


FIG. 507 Drawing illustrating the elastic band test. An elastic is placed around the head causing venous congestion thus making the vascular supply perceptible through the skin.

enough to reach the blood vessels (Fig 508B) The vascular pedicle with its layer of subcutaneous tissue is dissected from the surrounding tissue as far upward as the hair bearing island of scalp (Fig 508C) The temporal vessels are clamped sectioned and tied above the island of scalp A subcutaneous tunnel is then prepared opening into the space made in the supraorbital region for the reception of the new eyebrow The island of scalp with its subcutaneous tunnel (Fig 508D) is carefully sutured into the new supraorbital position (Fig 508F). This method generally insures the vitality of the hair follicles and the restoration of a full eyebrow Although the hair may fall out shortly after the transplantation regrowth occurs subsequently Figure 509 shows reconstruction by an artery island flap for loss of the lateral half of the left eyebrow

Temporal Scalp Flap

A direct flap from the temporal region may be employed for eyebrow restoration. A long narrow pedicled scalp flap can be transferred successfully from the temporal area if the flap is delayed by outlining incisions (Fig 510)

In all eyebrows reconstructed from the scalp the patient is obliged to trim the new hairs periodically because they grow to excessive length

Flap from the Unaffected Eyebrow

A median defect of the eyebrow is repaired with a flap from the unaffected eyebrow in individuals with thick eyebrows (Fig 511) The recipient area is prepared by extending a horizontal incision laterally from the frontal eminence The upper half of the unaffected eyebrow is outlined in

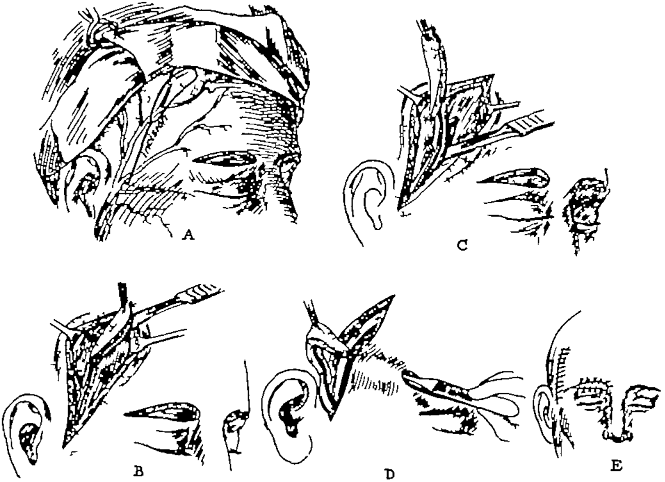


FIG 508. The artery island flap reconstruction of the eyebrow

A. Drawing illustrating the outlining of a portion of the scalp over the temporal vessels.

B. A superficial incision through the skin does not include the blood vessels. The vascular pedicle, with its layer of subcutaneous tissue, is dissected, including the portion of scalp to be used.

C. The flap with its blood supply is separated from its base.

D The island flap is passed through a subcutaneous tunnel leading into the space over the supraorbital ridge.

E. Suturing is then completed.

FIG 509

(*Left*) Photograph showing absence of the outer half of the left eyebrow

(*Right*) Photograph following repair by an artery island flap

cised and elevated on a comparatively broad, thick pedicle in the region of the root of the nose the flap is then transferred and sutured into position Although narrow at its extremity the flap is dissected with a sufficient amount of underlying tissue down to the periosteum, in order to assure an adequate blood supply (Fig 512)

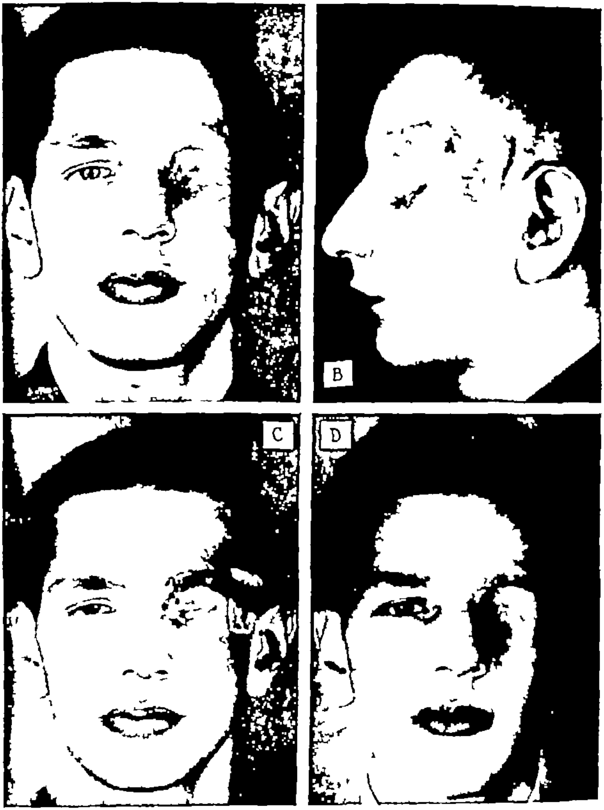


Fig. 510 Replacement of eyebrow by delayed temporal scalp flap

A Left orbit exenterated and eyebrow destroyed by radiation

B A long temporal scalp flap was delayed

C Scalp flap after transfer

D Result obtained

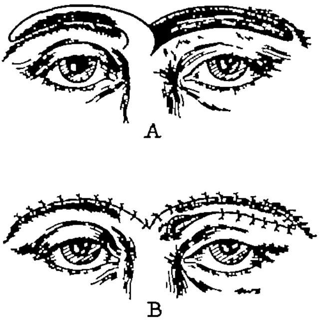


Fig 511 Reconstruction of eyebrow by pedicled flap from unaffected eyebrow

A. Outline of flap consisting of the upper half of unaffected eyebrow

B. The pedicled flap is transferred to its new position.

DEFORMITIES OF THE FOREHEAD FROM LOSS OF BONE

Such deformities may be due to loss of the anterior wall of the frontal sinus or of the full thickness of the frontal bone with resulting flatness or depression in the supra orbital region The loss may extend to the greater portion of the frontal bone and part of the parietal bones.

Full thickness defects of the frontal bone result in depression of the forehead, the dura being immediately subcutaneous. Pulsations of the brain are observed. The method of choice for repairing such deformities varies according to the size and location of the defect. The implants used are bone and cartilage or inert substances such as metal and plastic materials.

Bone Grafts

Transplanted bone supplies a firm protective covering for the brain and restores the contour of the frontal area when in contact with the adjacent bone of the skull (Fig 513) Large defects may be repaired in one operation or by successive grafts

The donor areas best suited are the ilium and tibia A bone graft from the inner table of the ilium is particularly useful when the defect involves the curved lateral portion of the frontal bone for the inner table of the ilium has a similar curvature.

Strips of bone 12 to 15 cm. in length and approximately 0.5 cm. in thickness may be obtained from the tibia This broad flat smooth bone is grooved with saw cuts on its undersurface and thus is rendered pliable the margins are shaped with either a rongeur or a saw

In children the split rib onlay bone graft is the technique of choice (Longacre and de Stefano 1956) for large defects. Sufficient bone is available from the costal area for the split ribs regenerate and may be employed a second time as grafts

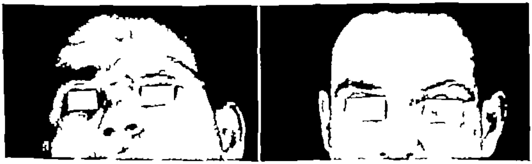


Fig 512

(*Left*) Photograph showing loss of the left eyebrow in a thick eyebrowed individual.

(*Right*) Correction of the defect following transfer of a portion of the unaffected eyebrow to the affected side.

A

B

C

D

Fig. 11. Repair of frontal bone defect by bone grafting.

A. Roentgenogram showing entire central portion of the frontal bone absent, the lateral aspect of the supraorbital ridge remaining.

B. Roentgenogram showing tibial bone graft filling the defect and creating normal contour.

C. Photograph, anterior view, showing frontal defect before operation.

D. Result achieved following tibial bone graft shown in B.

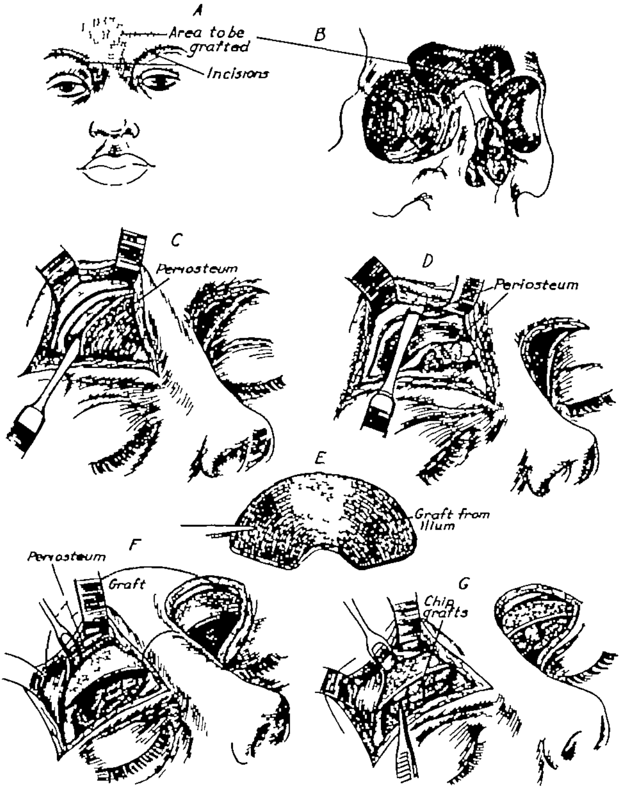


Fig 514

A. The dotted area represents the defect in the frontal bone. Incisions for exposure are made in the eyebrows, the site of previous operative scars.

B. Illustrates the defect in the frontal bone.

C. Shows exposure of the area. An incision has been made through the periosteum above the defect and the periosteum is reflected into the defect.

D. The periosteum is raised around the defect for a distance of 2 to 3 cm.

E. Shows the shape of the graft removed from the inner table of the ilium. The graft consists of the inner table with cancellous bone.

F. The bone graft placed over the defect has subperiosteal contact with the bone surrounding the edges of the defect. The lower margin of the bone graft has been suitably shaped to restore the contour of the supraorbital arches.

G. Cancellous bone chips are placed between the dura and the overlying main bone grafts.

(From J. M. Converse, Plast. & Reconstruct. Surg. 54:332, 1954)

Operative Procedure

Intratracheal anesthesia is usually employed. The bone defect is exposed, generally through cutaneous scar lines which are excised (Fig. 514*A*). A flap of scalp is raised in some cases, in order that the skin suture lines are not located over the bone graft. In raising the flap the galea aponeurotica and the frontalis muscle must be dissected from the underlying dura until the edges of the defect are completely exposed. An incision is then made through the periosteum of the bone surrounding the defect and the periosteum is reflected toward the edge of the defect and into it (Fig. 514*C*, *D*).

A bone graft of proper thickness and

FIG. 515. Reconstruction of the frontal bone. Before (A and C) and after (B and D) bone grafting by technique illustrated in Figure 514.
(From J. M. Converse and R. M. Campbell, S. Clin. of North America 34: 175, 1954.)

size (Fig 514E) is removed from the inner table of the ilium and is shaped to conform to the desired external contour of the defect with rongeurs and rasps. The graft is then fitted into position and chips of bone are added to complete the union between the graft and the frontal bone (Fig 514F G) The skin wounds are sutured and a carefully applied pressure dressing is maintained for five to seven days. Figures 513 and 515 are examples of frontal bone defects repaired by bone grafts (Kazanjian and Converse 1940 Converse 1954)

Fig. 516
(*Upper*) Roentgenogram showing loss of the entire frontal bone.
(*Lower*) Roentgenogram showing solid vitallium plate with flanges, restoring defect.

A B C D

FIG. 517 Repair of frontal bone defect with vitallium plate
A and B Depressed frontal area due to loss of frontal bone
C and D Restoration of contour by vitallium plate

Cartilage Grafts

Chips of cartilage are placed into the defect and immobilized by a pressure dressing (Peer 1943) the cartilage grafts become joined and surrounded by fibrous tissue. Cartilage grafts may result in an irregular contour in large defects and because of this, are less satisfactory than bone.

Metallic and Plastic Implants

The authors prefer bone grafts for filling frontal defects, although implants of inert non-organic materials such as vitallium, tantalum and acrylic resins have been used successfully. Figures 516 and 517 illustrate results achieved by the use of such implants when surgery was contraindicated due to the magnitude of the defect or because of the irreconcilable attitude of the patient.

Non vital materials should be anchored to bone to ensure a satisfactory result; even slight motion creates enough disturbance to endanger the usefulness of either *metals or plastics. Although inert materials* may be tolerated by the tissues for a period of time, they are often extruded because of tissue irritation around an implant which has been placed in areas of functional stress, or when it is subjected to muscular *movements or trauma. A bed of dense* fibrous tissue remaining behind the rejected implant complicates further reconstructive procedures. Implants of foreign material are tolerated better in parietal defects, where there is relatively little motion of the covering scalp than in the frontal area where movements of the frontalis muscle cause irritation of the soft tissues due to friction against the implant.

21

DEFORMITIES OF THE EYELIDS, ORBITAL AND ZYGOMATIC REGIONS*

Deformities in the region of the orbit may involve the eyelids the bones of the orbit, or the eyeball and its appendages Severe deformity results from full thickness loss of eyelid tissue, malunited fractures with fragments impinging on the ocular globe, damage to extraocular muscles or destruction of the entire orbital contents.

Many deformities of the skeletal framework of the orbit are complicated by serious functional disturbances of the eyeball resulting in its functional impairment.

ANATOMICAL CONSIDERATIONS

The Orbits

The middle third of the face includes the portion of the face situated between two horizonal lines extending through subnasale below and nasion above (see Chapter 14) This area may be divided into three portions, a central or nasomaxillary area and two lateral areas, the orbitozygomatic or maxillozygomatic areas (Fig 518) The nasomaxillary area comprises the nasal structures which rest upon the maxilla in front of the interorbital space. The lateral or orbitozygomatic areas discussed in this chapter are formed in large part by the orbital cavities.

The components of the orbital cavities are the frontal bone the lesser and greater wings of the sphenoid the zygoma the maxilla the lacrimal bone and the ethmoid. The ocular globe is surrounded by a cushion of orbital fat within the orbital cavity The orbital contents are maintained in position by the septum orbitale, a fascia inserted on the inner aspect of the rim of the orbit (Figs. 519 520) The eyeball is protected by the orbital ridges which are exposed to trauma because of their prominence. Serious functional disturbances may arise from the displacement of these bones due to the close relationship of the orbital rims to structures in the orbital cavity

The supraorbital nerve and more medially the trochlea of the superior oblique muscle are located along the superior rim of the orbit (Fig 521) The tendon of the superior oblique muscle functions in a cartilaginous pulley or trochlea which is fixed by ligamentous fibers just behind the superomedial angle of the orbital margin. Fractures involving the superior rim of the orbit may result in compression of the supraorbital nerve with consequent anesthesia Diplopia may also result from injury to the pulley of the superior oblique muscle thus affecting the balance of the extraocular muscles. The lacrimal gland is lodged in the lacrimal fossa behind the lateral portion of the superior rim of the orbit (Fig 521)

The frontal process of the maxilla and the lacrimal bone share in the formation of the groove for the lacrimal sac (Fig 521)

* Prepared in collaboration with Byron Smith M.D Surgeon Director in charge of Ophthalmic Plastic Surgery Manhattan Eye, Ear and Throat Hospital, New York.

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A and B. Depressed frontal area due to loss of frontal bone.
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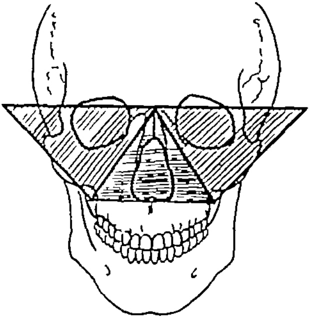

FIG. 518 Diagram dividing the middle third of the face into three triangular areas a central nasomaxillary and two lateral maxillozygomatic areas.

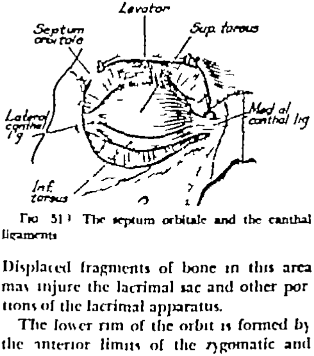

FIG. 519 The septum orbitale and the canthal ligaments

Displaced fragments of bone in this area may injure the lacrimal sac and other portions of the lacrimal apparatus.

The lower rim of the orbit is formed by the anterior limits of the zygomatic and maxillary components of the orbital floor When the floor of the orbit is displaced downward the lowered level of the eyeball may produce diplopia Diplopia may also be the consequence of injury to the inferior rectus muscle due to fragmentation of the floor of the orbit Escape of orbital fat through the fractured orbital floor into the subjacent maxillary sinus is the most frequent cause of traumatic enophthalmos.

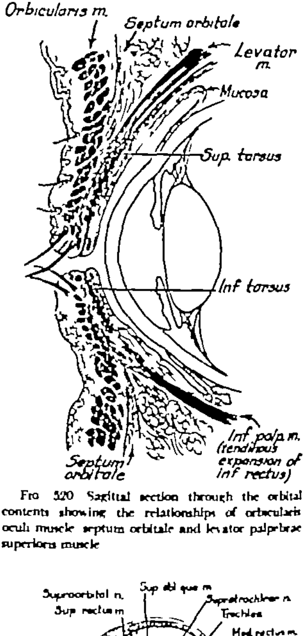

FIG. 520 Sagittal section through the orbital contents showing the relationships of orbicularis oculi muscle septum orbitale and levator palpebrae superioris muscle

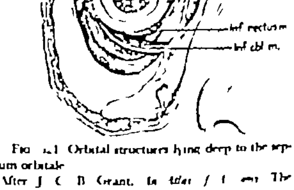

FIG. 521 Orbital structures lying deep to the septum orbitale (After J. C. B. Grant, An Atlas of Anatomy, The Williams & Wilkins Co. 19)

The Eyelids

The eyelids, composed of conjunctiva tarsus, fascia muscles and skin, protect the eyeball The tarsal plates (Fig 522) are semirigid structures of dense connective tissue encasing the tarsal glands The orbicularis oculi muscle, surrounding the palpebral fissure is responsible for lid closure its fibers insert into the bone by means of the medial and lateral palpebral ligaments (Fig 522) The levator palpebrae superioris muscle, responsible for raising the upper eyelid is inserted into the upper conjunctival fornix, upper portion of the tarsus, orbicularis oculi muscle and skin (Fig 522) The expansions of the levator are attached to the medial and lateral palpebral ligaments and are important surgical landmarks when attempting to locate the severed muscle.

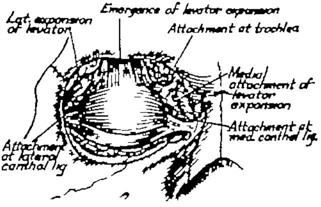

Fig 522 The levator palpebrae superioris and its relationship to the tarsus and canthal ligaments.

The extremities of the tarsal plates unite to form the palpebral ligaments which anchor the eyelids to the bony orbit in the transverse plane (Fig 522) The tarsal plates are loosely attached to the periosteum of the orbital margin in other areas by the thin palpebral fascia. The other bony attachment of the eyelids is by means of the orbicularis oculi muscle which is inserted along the medial margin of the orbit.

The orbicularis oculi muscle consists of concentric fibers which sweep around the lids and orbit in a continuous sheath. The muscle consists of two portions, a palpebral portion within the lids composed of thin pale fibers which lightly close the palpebral fissure on contraction and an orbital portion, the fibers of which are thick and red in color and are responsible for the forcible closure of the eyelids. The eyelids are maintained in contact with the eyeball by the normal tone of the muscle fibers, aided by atmospheric pressure and also through the pull of Horner s muscle on the medial palpebral ligament (Fig 523) Contact of the lid with the globe is maintained by the levator palpebrae superioris when the upper eyelid is elevated the direction of the muscle pull is upward and posteriorly when the levator contracts

Closure of the upper eyelid in paralysis of the seventh nerve is produced by relaxation of the levator palpebrae superioris muscle, which is innervated by the third cranial

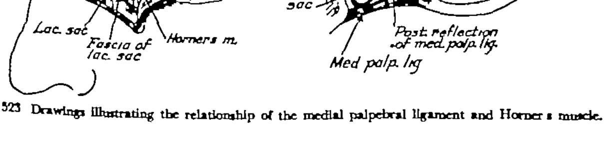

Fig 523 Drawings illustrating the relationship of the medial palpebral ligament and Horner s muscle.

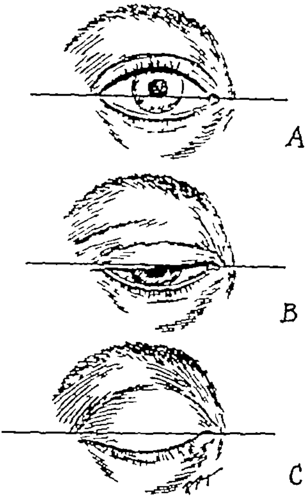

FIG 524

A. In the forward gaze the medial and lateral canthi are situated along the same horizontal plane

B and C. As the upper eyelid descends it extends below the horizontal plane Closure of the palpebral fissure is produced mainly by the downward displacement of the upper eyelid.

nerve the eyelid descends by gravity It is not possible for the patient to squeeze the eyelids together because of the paralysis of the orbicularis oculi muscle

The skin of the eyelids is folded upon itself the excess of skin permitting closure of the palpebral fissure In the foreward gaze the upper limit of the tarsus of the upper lid is demarcated by a transverse crease the superior palpebral fold (Fig 524A) The tarsus disappears under an overlapping fold of the upper part of the lid when the eyelid is raised. The tarsus of the lower lid is much smaller and the skin covering the tarsus lacks such definite demarcation. Closure of the palpebral fissure is produced mainly by the downward displacement of the upper eyelid (Fig 524B C) When the eyelid is raised the tarsus disappears under an overlapping fold of the upper portion of the lid Blinking movements of the lids are due to contraction of the palpebral fibers of the orbicularis oculi muscle which acts as an antagonist to the levator palpebrae superioris muscle.

The skin of the eyelids, thinnest of the entire body is intimately bound to the underlying orbicularis oculi fibers. The eyelid skin becomes thicker at the junction with the skin of the cheek and of the other areas surrounding the orbit, the area of transition corresponding roughly to the bony orbital margins (Fig. 525).

The conjunctiva lines the inner aspect of the eyelid and is reflected onto the ocular globe The tarsal conjunctiva is densely adherent to the tarsal plates the remainder of the conjunctiva is loosely bound to the underlying epibulbar and fornix tissues. The depth of the conjunctival cul-de-sac varies a diagrammatic representation of the depth of the cul-de-sac is represented in Figure 526

The eyelids have unusual mobility and

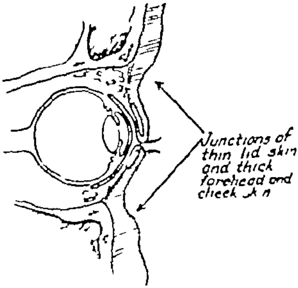

FIG 525 Diagram demonstrating the difference in thickness of the cutaneous tissues at the orbital margin where the eyelid skin meets the surrounding facial skin

are therefore vulnerable to the effects of scar contracture whether within themselves or in the adjacent tissues.

Sensory Innervation

An awareness of the sensory innervation is important, local anesthesia being frequently employed for operations in the orbital region. The eyelids are innervated by the ophthalmic and maxillary nerves which are distributed from the trigeminal ganglion in Meckel's trigeminal cave a space in the floor of the middle cranial fossa immediately near the apex of the petrous portion of the temporal bone.

The ophthalmic nerve first division of the trigeminal enters the orbital cavity through the superior orbital fissure, distributing lacrimal frontal and nasociliary branches (Fig 527) The lacrimal nerve contributes afferent filaments to the lacrimal gland and to the upper eyelid and skin in the region of the lateral orbital border The frontal nerve, bifurcating in the orbital cavity into supraorbital and supra trochlear branches, transmits sensation from the skin of the forehead and scalp the frontal sinus, the region of the inner angle of the eye and the root of the nose. The nasociliary nerve is distributed mainly to the internal and external nose.

The maxillary nerve second division of the trigeminal leaves the cranium through the foramen rotundum, traverses the pterygopalatine fossa supplies short sphenopalatine nerves to the sphenopalatine ganglion zygomatic nerve and posterior-superior alveolar nerves and continues through the infraorbital canal or groove in the floor of the orbit. The portion of the maxillary nerve in the orbital floor is referred to as the infraorbital nerve (Fig 528) The zygomatic nerve is the orbital branch of the maxillary nerve, branching from the latter in the pterygopalatine fossa and extending through the inferior orbital fossa into the orbit where it bifurcates into zygomaticotemporal and zygomaticofacial branches

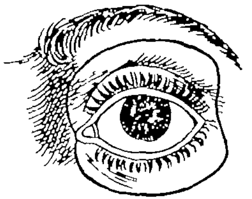

Fig 526 The depth of the conjunctival fornix is outlined in this diagram.

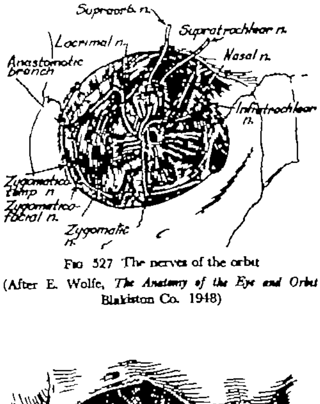

Fig 527 The nerves of the orbit
(After E. Wolfe, *The Anatomy of the Eye and Orbit* Blakiston Co. 1948)

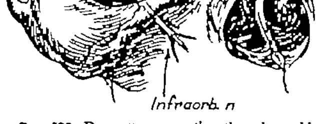

Fig 528. Diagram representing the relationship of the maxillary and infraorbital nerves with the orbital cavity

(Fig 527) The zygomaticotemporal nerve joins the lacrimal nerve in the orbit reaches the temporal fossa by way of the zygomaticotemporal foramen in the zygoma penetrates the temporal fascia and transmits sensation from the skin of the anterior temporal region, anastomosing there with neighboring filaments of the facial nerve The zygomaticofacial nerve passing through the zygomaticofacial foramen on the outer surface of the zygoma conducts sensation from the skin of that region of the face and anastomoses with terminal filaments of the facial nerve

The infraorbital nerve after giving off middle and anterior superior alveolar branches from the floor of the orbit emerges upon the face through the infraorbital foramen and subdivides into terminal branches which include the inferior palpebral external nasal and superior labial nerves.

Block anesthesia of the eyelids may be achieved by injecting at various points along the superior rim of the orbit to anesthetize the lacrimal frontal supraorbital and supratrochlear nerves. Additional injections in or near the infraorbital foramen and in the region of the zygomaticofacial foramen on the lateral surface of the zygoma result in block anesthesia of both upper and lower lids.

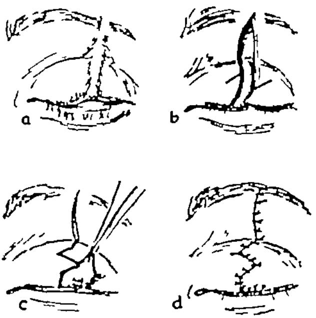

Fig 529 Diagram shows excision of scars (A and B) and the lid margins brought together by the stepping method (C) To prevent recurrence of contracture the vertical suture line is carried out in a zig zag manner (D)

DEFORMITIES OF THE EYELIDS

Eyelid deformities from trauma are due to scar contracture malposition or distortion of the tissues through faulty suturing of a laceration and varying amounts of tissue destruction or they may be due to contractures resulting from burns. Such deformities may involve the skin alone or include the lid margin a part of the full thickness or the entire full thickness of the lid.

Scars

Deformity from contracture without appreciable loss of tissue is usually caused by vertical scars which pull the lid out of normal alignment cause notching of the free margin or ectropion or entropion. Horizontal lacerations seldom cause contracture

In the surgical correction of such deformity the scars are excised in order to restore the normal outline of the lid margins. Direct approximation and suture of the wound even when done with great precision is usually followed by a recurrence of the linear contraction It is necessary therefore to avoid a straight line of suture by producing a zig zag line employing the stepping Z plasty or tongue and groove techniques (Fig 529) If excision of the scar and readjustment of the eyelid require penetration through the entire thickness of the eyelid the various layers should be decussated and overlapped by procedures such as the halving technique (Wheeler 1939) in order to minimize contraction during healing When the scar involves the full thickness of the lid after approximating the lid margins a flap of skin is advanced over the suture line to further interrupt the straight line of junction (Fig

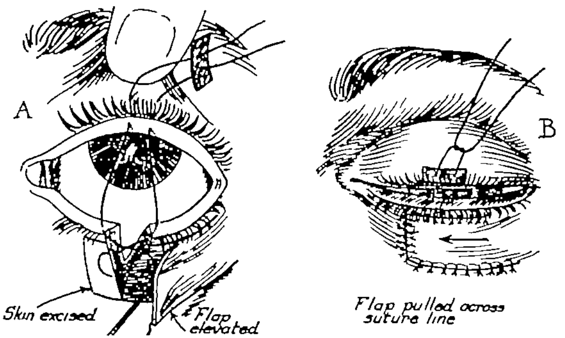

FIG. 530. Use of a figure-of-eight suture and an overlapping advancement flap to join the margins of the lower eyelid in order to avoid notching

A FIG 531 B

A. Notching and ectropion of the lower lid from vertical scar

B. Photograph following repair by excision of the scar and techniques illustrated in Figures 529 and 530

530) Figure 531 illustrates such a scar contracture of the lower lid with notching that was corrected by the procedure shown in Figure 530

General Care of the Globe

The eye is washed with normal saline solution following ophthalmic procedures a bland ointment is placed along the palpebral fissure before the pressure dressing is applied. Postoperative ocular pain and a grit like sensation usually indicate abrasion or ulceration of the cornea due to friction of the dressing, the presence of a foreign body or irritation by an eyelash. These symptoms are an indication for the removal of the dressing to examine the globe. A temporary horizontal mattress suture should always be placed through the upper and lower lids joining them thus offering protection to the cornea whenever a pressure dressing is placed over the eye

Suture for Lid Closure

Temporary lid closure may be achieved by inserting a simple horizontal mattress suture (Fig 532) tied over gauze or rubber dam material to prevent cutting the skin. A double-armed suture, with a needle at each end is used for this procedure. The

sutures are placed from below upward in order that the knot be tied in the upper lid. This precaution facilitates removal of the suture for the knot in the upper lid is easily located even in edematous tissues. Eyelid occlusal suture is a precautionary measure preceding the application of a pressure dressing over the face to avoid corneal abrasion resulting from opening of the eyelids under the dressing

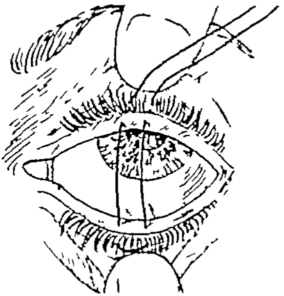

FIG 532. Occluding suture used to prevent opening of the palpebral fissure and corneal abrasion when a pressure dressing is placed over the eye

Tarsorrhaphy

Tarsorrhaphy is the technical term for interpalpebral or lid adhesions. Partial or complete tarsorrhaphy is occasionally indicated as a protective device or therapeutic measure.

Partial Tarsorrhaphy

A rectangular area about 5 mm. in length is denuded along the margins of each lid and the lids are then occluded by a mattress suture (Fig 533) a *horizontal mattress* suture of 4-0 silk is used to approximate the raw areas. It is advisable to split the eyelid into outer and inner layers by an incision along the white line of the lid, to avoid loss of contact between the eyelids due to stretching of the scar tissue

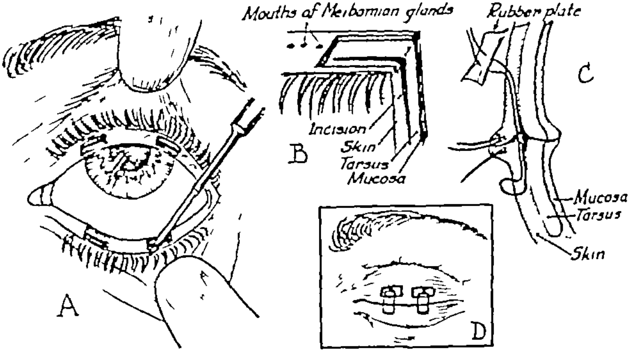

FIG 533. Technique of partial tarsorrhaphy

A Excision of two small rectangles along the margin of each eyelid. Splitting the margin of the eyelid into inner and outer layers.

B Detail of the eyelid margin splitting incision

C Technique of placing suture

D The raw areas of the eyelids are maintained in contact by means of mattress sutures

that joins the denuded areas of upper and lower eyelids (Fig 533B C) This incision lies between the base of the hair follicles of the eyelashes and the Meibomian glands (Fig 533)

Complete Tarsorrhaphy

In complete tarsorrhaphy the procedure outlined in Figure 533 is extended to the entire free margin of each lid (Fig 534) a continuous suture is then looped back and forth from one raw area to another and finally pulled tight to occlude the lids. A pinpoint opening is usually left between the lids at each canthus to allow drainage of the conjunctival sac.

Burn Deformities of the Eyelids

Intense heat plays momentarily on the body in flash burns, causing devitalization of the exposed parts and often a deep burn with total skin loss ordinary clothing provides surprisingly effective protection. In flame burns, on the contrary the period of exposure to the heat is prolonged although the burning agent is of lesser intensity

Burns of the face also occur in patients who lose consciousness and fall into open fires or are trapped under wreckage in a burning house The lesions in such cases are deep because of longer exposure of the area to the burning agent. Such burns are seen in epileptics, infants, or senile patients.

Chemical burns are the result of industrial accidents or of acid throwing during an act of vengeance. The structures behind the lids are not injured in flash or flame burns. Corneal and conjunctival burns do occur in chemical burns, however and are particularly serious because spreading infection of the eye from a corneal ulcer may require enucleation. The cornea was destroyed by acid in one of our patients who had suffered such an attack and infection led to endophthalmitis resulting in loss of the eye. Household lye is commonly employed in such assaults.

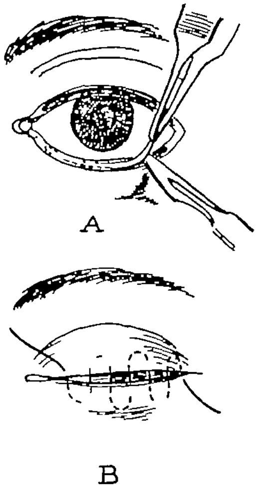

Fig 534 Complete tarsorraphy

A. The greater portion of the margin of each lid is denuded.

B The lids are held occluded by a continuous suture.

Corneal ulceration and scarring are seen in long-standing ectropion following flash or flame burns from exposure drying and subsequent infection. Most corneal lesions in burn cases are preventable if precautions are taken to protect the cornea from exposure

Intrinsic and Extrinsic Burn Scars of the Eyelids

Because the eyelid skin is thin burns usually cause greater tissue destruction than in the thicker skin of the face The eyelids consist of loosely attached tissues, and are readily submitted to the pull of contracting healing burned tissues over the periphery of the orbital rims. A distinction should therefore be made between *intrinsic* burn scars of the eyelids in which the cause

Fig. 533. Typical case of ectropion of the eyelids resulting from burns

of burn ectropion is primarily in the eyelids themselves, and *extrinsic* burn scars, in which there is considerable burning of the surrounding tissue (Fig 535). This distinction is important clinically, indicating the need for replacement of the eyelid skin proper and also of the adjacent skin.

Burn contractures may involve eyelid tissue alone when the remainder of the face has suffered only a superficial burn. Because the eyelid skin is thin and the eyelids are loosely bound tissues, contraction during healing results in ectropion.

The eyelids are often spared in flash burns if the patient is wearing glasses but the skin of the remaining portion of the face can be burned and scar contraction of the surrounding tissue may cause extrinsic ectropion.

Ectropion

Ectropion, a characteristic deformity, results unless skin replacement has been provided in the early stages (Fig 533). The degree of ectropion depends upon the extent of tissue loss. Because the tarsal plate of the lower lid is smaller than that of the upper lid, a lesser loss of lid tissue will produce ectropion of the lower lid. Moderate loss of tissue of the upper lid causes the lid to be pulled upward and forward from the eyeball; closure of the palpebral fissure becomes impossible because of the shortness of the lid. Additional tissue loss produces greater shortness of the lid, causing the lid to be turned upon itself; the conjunctival surface is then exposed due to eversion of the tarsal plate. Ectropion of the upper lid is always a serious complication because of resulting corneal exposure and the danger of corneal drying and ulceration. The danger of corneal ulceration is lessened when the ectropion is limited to the lower lid, for the closure of the palpebral fissure is essentially performed by the upper lid (Fig 521).

Ectropion of the lower eyelid occurs rapidly due to the smaller size of the tarsal plate and the influence of gravity. In its mildest form, the lower lid is pulled forward from the eyeball; epiphora is one of the early symptoms of such ectropion. In its more serious form, the lid is pulled down and gradually turned inside out by eversion of the tarsal plate. Both upper and lower eyelids are turned inside out in extreme ectropion. The lateral canthus tends to be displaced upward and outward due to the pull of scar tissue at a distance; the medial canthus is pulled forward and medially toward the bridge of the nose (see Fig 555*A*). Both lacrimal puncta are pulled forward away from the eyeball, completely disturbing the function of the lacrimal apparatus.

In severe burns, in addition to ectropion, narrowing of the palpebral fissure is due to scar tissue which forms at the angles of the eye, covers the caruncle medially and tends to create a traumatic tarsorrhaphy in the lateral canthus; a vertical contractile band is frequently noted.

Even in deep burns of the eyelids with full-thickness destruction of the skin a sufficient number of orbicularis oculi muscle fibers remain to insure closure of the eye. Function of the levator palpebrae superioris muscle is rarely affected Even when the eyelids have been involved in full thickness burn of the skin although the eyelashes and eyebrows are scorched the eyelid margins are usually spared and the tarsal plates remain intact.

Deep burns which involve the full thickness of the eyelid or chemical burns, with penetration of the burning agent into the conjunctival sac, result in symblepharon an adhesion between the eyelid and eyeball complete obliteration of the conjunctival sac is known as ankyloblepharon The treatment of burn deformity of the eyelids resulting from loss of a full thickness portion of eyelid is described later in this chapter (see Fig 577)

Choice of Grafts for Burn Ectropion of the Eyelids

A full thickness graft of eyelid skin provides the most satisfactory skin cover for the eyelids. Such a graft can be taken only from an unburned upper lid Because the available area is limited, the method is not applicable in many burn cases, but may be employed in other types of ectropion. A full thickness graft of skin from the postauricular or supraclavicular regions is the graft of choice for lower lid defects. The relative lack of suppleness of this full thickness skin is of no significance in the lower lid which has relatively little motion such a graft however is unsuitable for use in the upper lid because its thickness prevents the formation of the palpebral fold (Fig 536) The postauricular graft tends to remain pink and slightly full the pink color of the graft matches well with the reddish tinge which frequently characterizes the skin of a healed burned face. A thin split thickness graft from the inner or anterior aspect of the upper arm is relatively hairless and is the most suitable type of skin graft for replacing upper eyelid skin for it remains thin and supple, permitting the graft to assume the horizontal folds characteristic of the lid (Fig 537) The color match as a rule improves in time although some grafts remain white or yellowish white in color This inconvenience is of lesser importance in the upper than in the lower lid because most of the upper lid is hidden in the normal forward gaze There is no particular advantage is using thick rather

FIG 536. Ectropion due to burns

A. Appearance of patient with bilateral ectropion.

B. Result of the use of the full thickness graft in the repair of contracture of the upper and lower eyelids at the age of six years. Photograph taken at twelve years of age shows good contour of the upper eyelids, although lacking the normal superior palpebral fold.

than thin split thickness grafts in the upper lid they are always less supple and may grow hair

Technique of Skin Grafting of the Upper Eyelids

The eyelids must be freed of scar tissue in order that the margin of the lid may be returned to its normal contact with the lower lid (Fig 538) Scar tissue excision should include both the skin scars and most of the subcutaneous fibrotic tissue Injury to the aponeurosis of the levator palpebrae superioris muscle must be avoided. Hemostasis is obtained by pressure and by fine tipped thumb forceps applied to the

A

B

Fig 537 Ectropion resulting from burns

A. Appearance of patient showing ectropion of right upper and lower lids.

B. Lower lid repaired with full thickness graft from behind the ear Upper lid defect repaired with split thickness graft. Note presence of normal appearance of horizontal fold in upper lid in comparison with that in Figure 536.

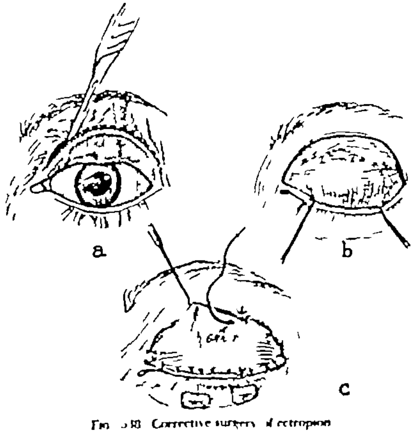

Fig 538 Corrective surgery of ectropion

A Incision made immediately above the lid margin, freeing the lid

B The lid is freed of scar tissue and the margin is brought down into its normal position and the defect becomes apparent

C. Skin graft applied to the defect *The graft may be permitted to overlap the edges of the defect when sutured* Two mattress sutures tied over gauze hold lids together

bleeding points which are electrocoagulated. A free full thickness graft is removed from the upper lid of the opposite eye when possible and the graft is then sutured to the edges of the defect by carefully placed interrupted sutures. Such a graft may be dressed as early as the third day

When a thin graft from the inner aspect of the arm is employed, the graft is spread over the defect and is permitted to overlap the wound edges. The margin of the upper lid is temporarily fastened to that of the lower lid by one or two interrupted sutures before the pressure dressing is applied over the skin graft to prevent the opening of the eyelid under the dressing, and to deter consequent corneal abrasion.

Immobilization of the area and pressure over the graft are obtained by a variety of methods. A covering of thin nylon material is placed over the graft. Absorbent cotton saturated with saline solution or pledgets of cotton impregnated with mineral oil prevent adherence between the dressing and graft. A pressure dressing retained by a bandage further immobilizes the region The cotton is again saturated with saline solution to facilitate its removal

Epithelial Outlay Technique for Burn Ectropion of the Upper Eyelids

This technique (Gillies, 1920) was popularized by McIndoe during the second World War Contraction of the skin adjacent to the eyelid can be anticipated in early grafting of extensive burns of the face. The dental compound mold technique is advantageous in such grafting since it permits the introduction of excess skin into the defect and allows for subsequent contraction of the surrounding skin. The ectropic eyelid must be freed of scar tissue by excision of the scar this excision must often be extended beyond the lateral rim

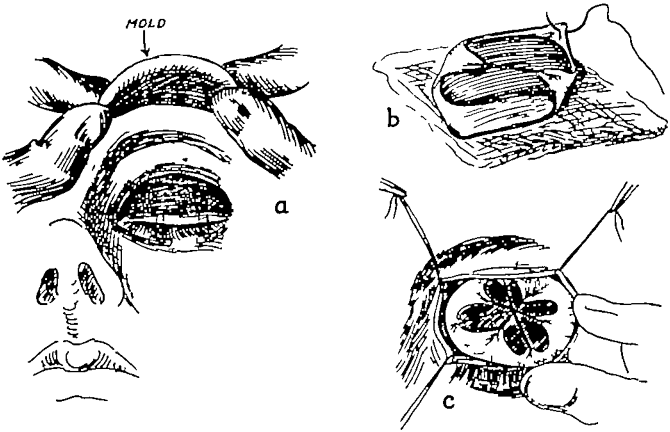

FIG 539

A. Dental compound molded over the defect.
B. The compound mold is covered with a skin graft, with the raw surface outward
C. The compound mold and graft are fitted into the defect and sutured.

of the orbit. Traction is exerted on a number of special everting vertical mattress sutures to distend the raw area of the lid (Fig 559) The wound edges are slightly undermined above medially and laterally for a distance of 0 5 to 1 cm to further increase the size of the raw area Softened dental compound is spread over the defect and introduced beneath the undercut edges of the wound The compound is chilled and hardened by a stream of sterile ice water and is removed from the wound.

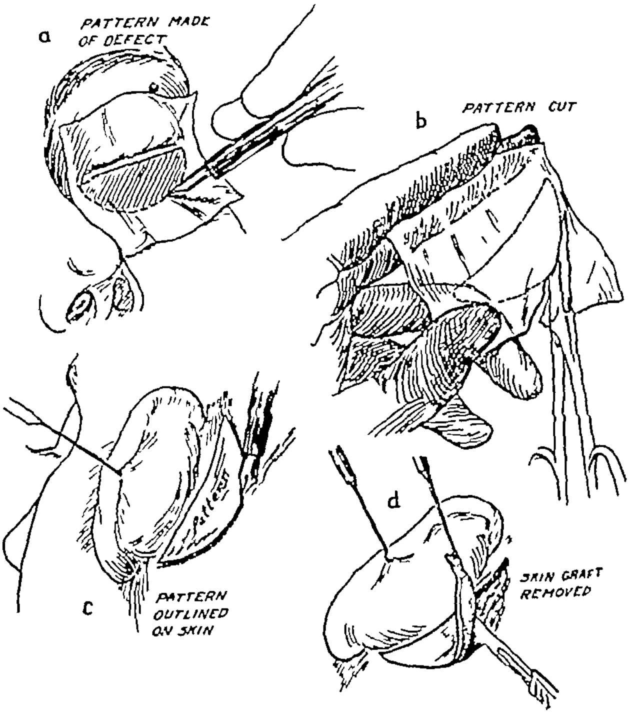

Fig 560 Full thickness graft for repair of ectropion of the lower eyelid

A Preparation of pattern of defect
B Cutting the pattern
C Tracing the pattern graft in the retroauricular area
D Removal of full thickness graft

The skin graft raw surface outward (Fig 539B) is then applied to the compound mold, placed into the defect and the long ends of the end-on mattress sutures are tied over the mold (Fig 539C) Pledgets of cotton and a pressure dressing are applied over the entire area.

The graft must not be disturbed when the mold is removed which is done at the time of the first dressing on the fifth post operative day The excess overlapping skin graft is trimmed with scissors and the grafted areas are left exposed. Protection by a dressing or an eye shield during sleep may be indicated during the next five days.

The technique is particularly useful in early skin grafting following burns, because it permits the grafting of a wide surface of skin and allows for both intrinsic and extrinsic contraction. When skin grafting of both upper lids is required the two procedures may be performed in one operative session. A binocular dressing decreases motion and promotes healing during the early postoperative period.

Technique of Skin Grafting of the Lower Eyelid

Although the thin mobile skin of the lower and upper lids are similar in structure thin grafts are less satisfactory than thicker grafts in the lower lid for the tendency toward recurrence of ectropion is greater in the lower lid the full thickness graft, which contracts to a lesser degree is preferable to the split thickness graft. Full thickness skin from the retroauricular region (Fig 540) or the supraclavicular area is selected for grafts because of the texture and the color match

The lower lid is completely freed of all scar tissue until the margin of the lid resumes its normal outline. The orbicularis oculi muscle is then enabled to function reapplying the lid against the eyeball Incisions should be extended medially and laterally in order that the graft can be applied in a sling like fashion it is carried medially to the nose and laterally above the outer canthus (Fig 541) This design is essential to maintain the support of the lower eyelid in order to counteract the effect of gravity and prevent a downward pull on the lid To compensate for the contraction of the skin graft during healing, the raw area of the lower eyelid may be

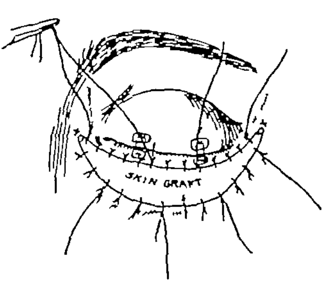

Fig 541 Repair of ectropion of the lower lid by full thickness retroauricular skin graft. The lower lid has been completely freed from adhesions and the upper and lower lid margins temporarily connected A postauricular full thickness skin graft is sutured in position.

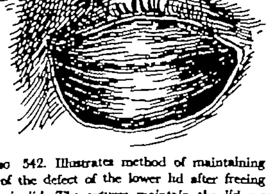

Fig 542. Illustrates method of maintaining the size of the defect of the lower lid after freeing the ectropic lid. The sutures maintain the lid margin at the correct level by preventing the upper lid from moving downward.

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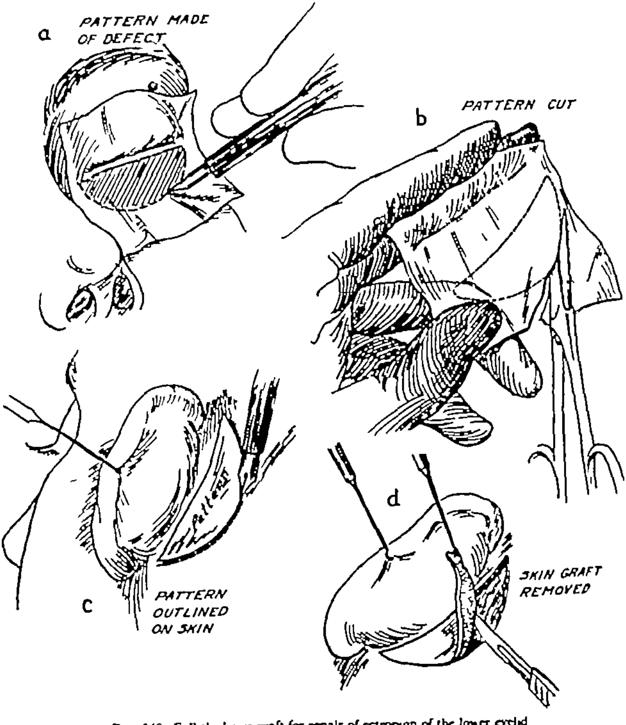

FIG 540 Full thickness graft for repair of ectropion of the lower eyelid

A Preparation of pattern of defect.
B Cutting the pattern
C Tracing the pattern graft in the retroauricular area.
D Removal of full thickness graft.

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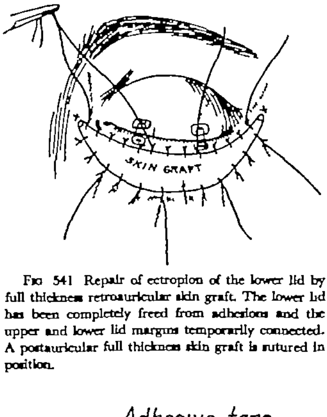


FIG 541 Repair of ectropion of the lower lid by full thickness retroauricular skin graft. The lower lid has been completely freed from adhesions and the upper and lower lid margins temporarily connected. A postauricular full thickness skin graft is sutured in position.

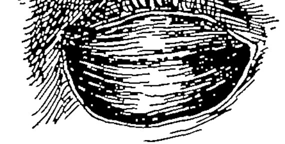


FIG 542. Illustrates method of maintaining the size of the defect of the lower lid after freeing the ectropic lid. The sutures maintain the lid margin at the correct level by preventing the upper lid from moving downward.

FIG 543 Skin grafting for burn-ectropion of the eyelids

A Photograph of patient showing ectropion of the lids resulting from burns caused by a gasoline explosion.

B Shows exposure of the eyeballs due to inability to occlude the lids.

C. Restoration of eyelid skin by grafting The upper eyelids were restored by a thin skin graft removed from the inner aspect of the arm and retained by the compound mold technique as shown in Figure 539. The lower eyelids were repaired by full thickness retroauricular graft as shown in Figures 540 and 541

D After skin grafting the patient is able to occlude the eyelids

maintained distended by the type of traction sutures illustrated in Figure 512.

The full thickness graft cut to pattern is anchored in place with the finest nonabsorbent suture material The long ends of a number of sutures are employed to retain a tied-in (bolus) pressure dressing (Fig 541) The dental compound mold should not be used in the lower lid because it endangers the cornea in this location Figures 543 and 544 show patients with burn ectropion of the eyelids before and after surgical correction by skin grafting

Contraction of Eyelid Skin Grafts

All healing wounds contract particularly in wounds with total skin loss Wound contraction is minimized by skin grafting but a

A  B

FIG 544 Marked ectropion of lower eyelid repaired with postauricular full thickness skin graft.
A. Preoperative photograph.
B. Photograph taken one year postoperatively

degree of contraction occurs during and after skin grafting The eyelids because they are mobile structures and loosely bound, are particularly susceptible to contraction Such secondary contraction may result in a recurrence of ectropion which although of a lesser degree may require additional skin grafting

Skin grafts applied to burned raw areas contract much more in the early weeks than later In cases of moderate burn ectropion without dangerous corneal exposure postponement for 4 or 5 weeks permits skin grafting under more favorable conditions with a minimum danger of subsequent contraction It must be emphasized however that in extensive skin loss of the eyelids such purposeful postponement of skin grafting may lead to dangerous exposure of the cornea and irrevocable deformity of the lids.

When the four eyelids require skin grafting in burn cases we have found it expedient to graft the two upper eyelids in one operative session The inconvenience of temporarily covering both eyes is compensated for by the advantage of immobilizing the eyelids, for when the patient is permitted the use of one eye motion of the eyelids of the opposite eye under the pressure dressing always occurs.

The grafting of the upper eyelids is frequently done under general anesthesia. The lower eyelid grafting may be done under local anesthesia if ectropion is not too extensive. Skin grafting the lower eyelids is usually done in two separate operative sessions to maintain the use of one eye.

The advisability of tarsorrhaphy as a step in ectropion treatment is controversial. We have found tarsorrhaphy unnecessary in the treatment of burn ectropion of the upper eyelids In grafting the lower eyelids, a temporary eyelid occluding suture is usually combined with a traction suture anchored on the forehead (Fig 542)

Pedicled Flap for Ectropion of the Lower Eyelid

The repair of lower lid ectropion of long standing, especially ectropion due to burn contracture may require a pedicled flap from the upper eyelid (Fig 545) or the temporal (Fig 546 547) or zygomatic regions (Fig 548) A temporal flap transposition is shown in Figue 549 In ectropion of the lower lid uncorrected for a long period of time the lid margin has elongated and the

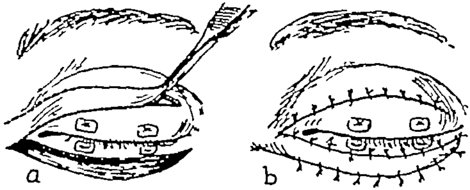


Fig. 545. Repair of ectropion of the lower eyelid by a pedicled flap of skin from the upper eyelid.

A. The flap from the upper lid is raised.

B. The flap has been transferred to the defect in the lower lid. This procedure is practically a free skin graft as the base of the pedicle is too narrow to ensure survival.

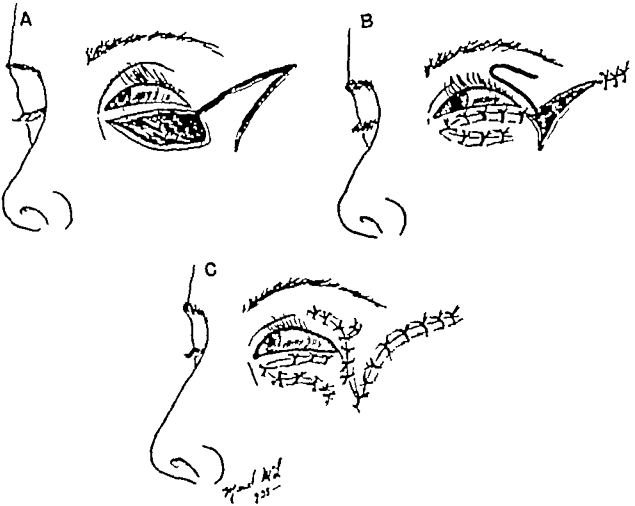


Fig. 546. Drawings illustrating marked ectropion of the lower eyelid repaired by temporal flap.

A. The lid margin is freed from adhesions.

B. A triangular flap from the temporal region is sutured in position to cover the raw area.

C. The donor area is closed by approximation of the borders and a small flap from the upper eyelid.

A  B

FIG 547 Photographs of patient before (A) and after (B) repair of the lower eyelid by the method shown in Figure 546

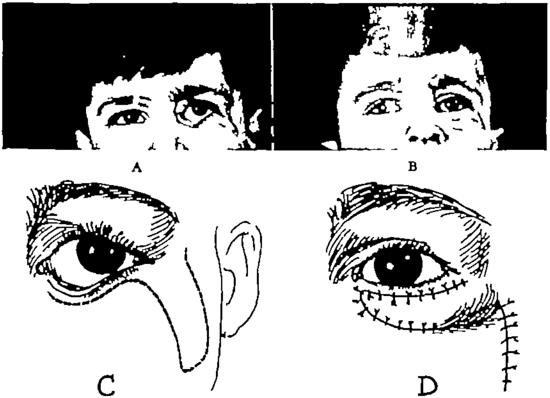


FIG 548 Correction of ectropion of the lower lid by a zygomatic flap.

A. Photograph of child with ectropion of left lower lid. Note the scar over the left zygomatic region

B. Correction of ectropion obtained by transposition of a zygomatic flap as shown in C and D

C. Outline of proposed zygomatic flap. The presence of a scar (see A) was influenced in the decision to use this type of flap.

D Illustrates transferred position of the flap.

conjunctiva has hypertrophied and is occasionally ulcerated It is necessary to excise a section of the lid margin and tarsus in such cases to restore adequate horizontal lid dimensions (Fig 549*B*) A satisfactory restoration of skin of the lower eyelid can be obtained with a temporal tongue-shaped flap in the majority of cases such flaps need not be delayed (Fig 549 550). The secondary defect in the temporal region is closed by direct approximation Slight partial ectropion of the lower eyelid on the nasal side is

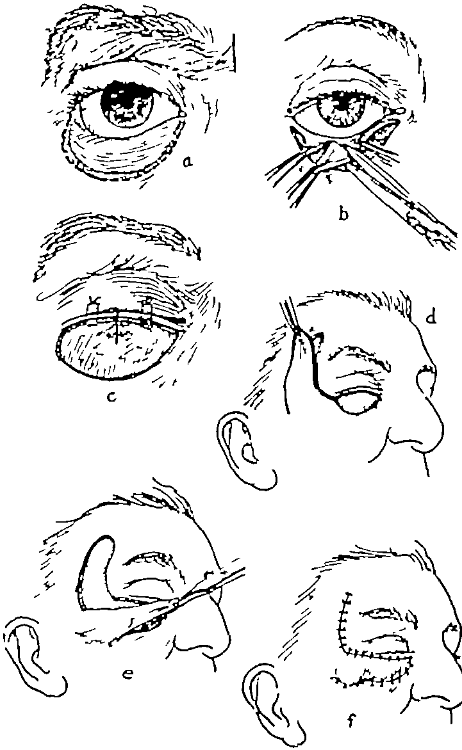


FIG. 549 Repair of ectropion of lower lid by a pedicled temporal flap

A Incision line below the lid margin separating the conjunctiva from the skin

B Section of conjunctiva excised and the borders brought together with buried sutures

C Lid margins temporarily sutured together

D Outline of temporal flap.

E and F Position of temporal flap to cover raw area below the lid margin

A Fig 550. B

A. Marked ectropion of the lower eyelid, of long standing with considerable hypertrophy of the conjunctiva.

B. Repair by temporal flap, the technique of which is shown by diagram in Figure 549

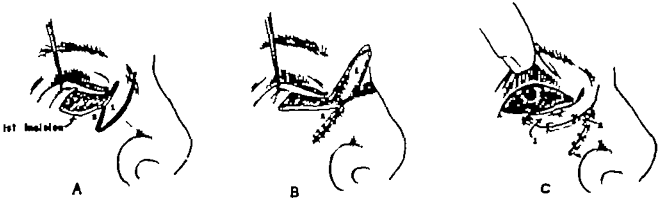


Fig 551 Diagrams illustrating repair of partial ectropion of the lower lid by a flap from the side of the nose.

A Eyelid margin released by incision below the margin

B. Nasal flap is raised.

C. Nasal flap transferred into the lid defect.

repaired by a flap from the side of the nose (Figs. 551 and 552).

Epicanthus

A semicircular fold medial to the inner canthus, following wounds or burns, is due to scars which extend from above downward toward the side of the nose. The deformity may also be due to fracture and depression of the bony support at the root of the nose. Scar deformities are corrected by excision of the scar and the use of Z flaps (Fig 553)

Another technique which has afforded good results is illustrated in Figure 554 Shortening of the medial canthal ligament by plication or by cutting the ligament and overlapping the two portions of the ligament (Fig 554*E*) is a frequent requirement when the structure has become elongated.

The transplantation of cartilage or bone is required when the deformity is due to loss of supporting bony structures of the nose.

Forward Displacement of the Medial Canthus

The inner canthus is drawn forward in injuries which result in the formation of ex

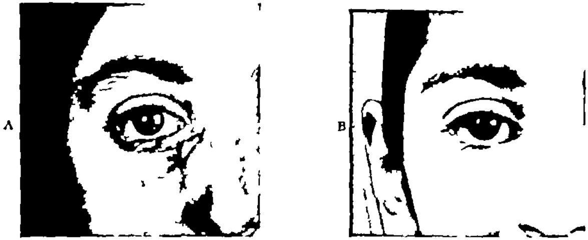


Fig. 552 Repair of partial ectropion of the lower lid by a flap from the side of the nose

A. Photograph showing ectropion of medial portion of the right lower lid.

B. Correction obtained by a nasal flap transferred according to the technique shown in Figure 551

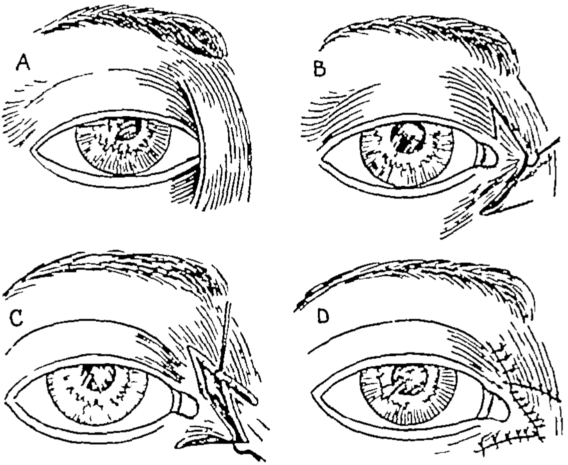


Fig. 553 Surgical correction of epicanthal fold

A. Outline of incision made along the fold

B. After the incision has been made along the epicanthal fold the Z flaps are outlined

C. Switching the Z flaps, the upper and lower flaps are transposed

D. Z plasty completed

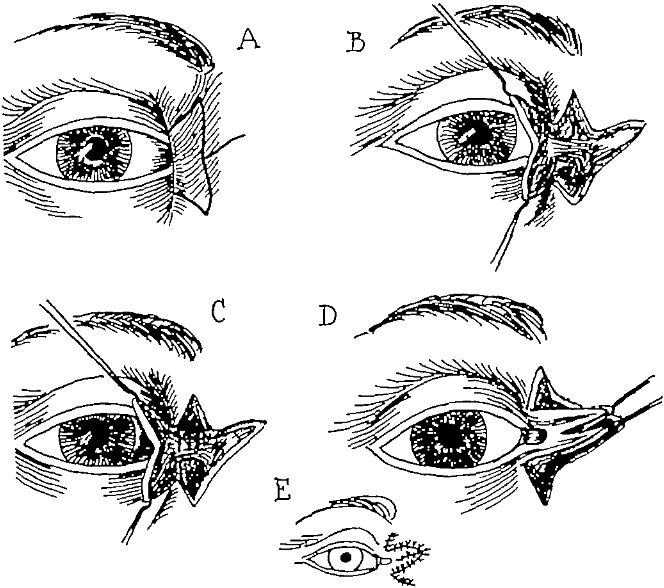


FIG 554 Surgical correction of epicanthal fold

A. Outline of incisions.

B. Exposure of medial canthal ligament.

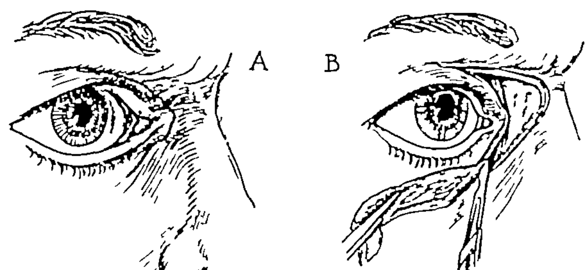
C. Shortening of medial canthal ligament by sectioning and overlapping the sectioned ends of the ligament.

D Shift of vertical flaps to a horizontal position.

E. Position of flaps after suture.

(Modified after V P Blair J B. Brown, and W H Hamm, Arch. Ophth. 7:831 1932 Am. J Ophth. 15:498, 1932)

tensive scar tissue as in burns, thus displacing the lacrimal puncta (Fig 555A) This condition occurs in deep burns over the root of the nose. Spontaneous healing in such areas tends to pull the skin of the medial canthal region forward, producing a peculiar epicanthal fold with a forward displacement of the medial portions of both eyelids (Fig 555A) The deformity resulting in epiphora from the absence of contact of the lacrimal puncta against the ocular globe, must be remedied by resecting the scar tissue freeing the canthus, and replacing it in its anatomical position The lacrimal puncta should be located prior to making an incision medial to the inner canthus to avoid cutting through the canaliculi A horizontal incision through the medial third of the skin of the upper and lower eyelid is required (Fig 555B) for the skin of the



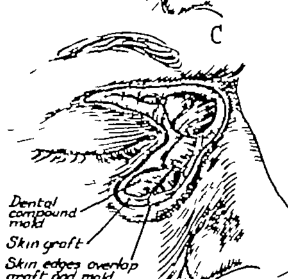


FIG 555 Technique of correction of epicanthal fold following burns.

A Typical epicanthal fold following burns of the medial canthal area and root of the nose The canthus is drawn forward displacing the lacrimal puncta forward

B. Excision of scar tissue and freeing of the canthus.

C. A skin graft maintained on a dental compound mold is placed in the area to cover the defect

(FIGURES 555 and 556 from J M Converse and B. Smith, Plast. & Reconstruct. Surg 2121 1949)

medial aspect of both the upper and lower eyelids is usually short in these cases. The medial canthus thus resumes a satisfactory position and the eyelid margins and the lacrimal puncta are once more applied to the globe The remaining raw area is skin grafted (Fig 555C) Three precautions must be observed to prevent a tendency for recurrence of the deformity (1) the skin edges of the defect over the nasal area should be widely undermined in order that the skin edges can overlap the graft which is maintained on a dental compound mold (Fig 555C) (2) the periosteum over the frontal process should be exposed In some cases it may be necessary to remove the periosteum to insure adherence of the skin graft to the bone (3) a thick skin graft should be employed to minimize subsequent contraction which is also lessened by the adherence of the skin graft to the denuded bone Revascularization of skin grafts transplanted over the bare bone occurs satisfactorily despite the removal of the periosteum

Elongation of the Palpebral Fissure

Shortening of the palpebral fissure is a complication in patients with severe burn ectropion of the eyelids, particularly when forward displacement of the medial canthus has occurred The technique for medial canthoplasty which has afforded us the best results is that suggested by Smith (19). After placing an ink dot at the point where the medial canthus should be situated an oblique incision is made through the outer

covering of the scar tissue which joins the eyelids (Fig 556*A*) A flap of tissue is raised (Fig 556*B*) exposing the inner lining of the scarred area An oblique incision in the opposite direction to the preceding one (Fig 556*C*) outlines a second flap lined by junctiva. Each flap is sutured over the surface of the eyelid margin (Fig 556*D* & A new medial canthus is thus formed posing the caruncle. The puncta shoul

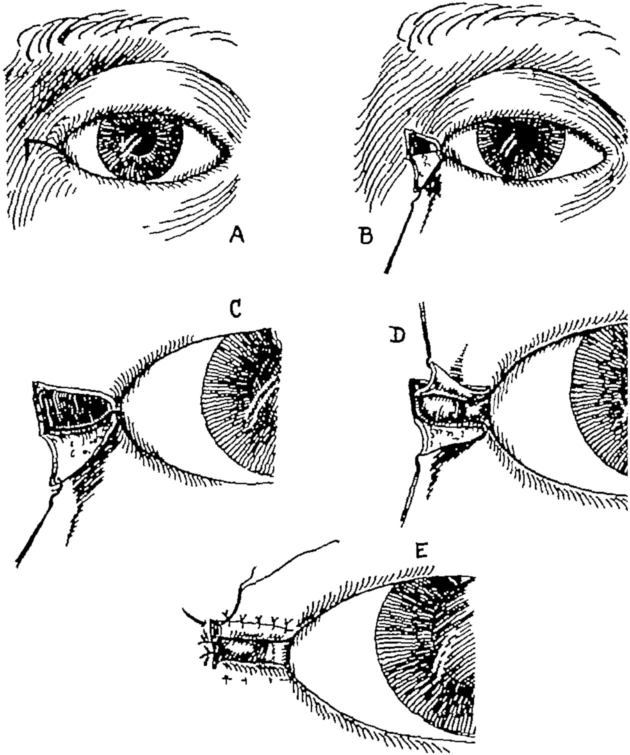


Fig 556. Canthoplasty for elongation of the palpebral fissure
A. An oblique incision is made through the outer covering of scar tissue.
B. A flap is raised exposing the inner lining of the scarred area.
C. An oblique incision is made in the opposite direction to the preceding one outlining a second of conjunctiva.
D & E. Each flap is sutured over the raw area of the eyelid margin.

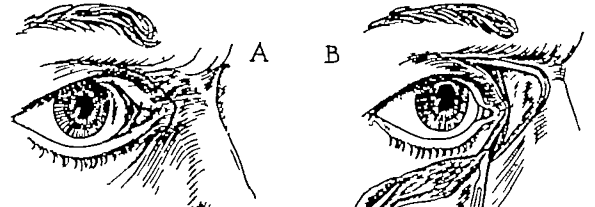


FIG 555. Technique of correction of epicanthal fold following burns.

A. Typical epicanthal fold following burns of the medial canthal area and root of the nose. The canthus is drawn forward displacing the lacrimal puncta forward.

B. Excision of scar tissue and freeing of the canthus.

C. A skin graft maintained on a dental compound mold is placed in the area to cover the defect.

(FIGURES 555 and 556 from J. M. Converse and B. Smith, Plast. & Reconstruct. Surg., 23:21 1959)

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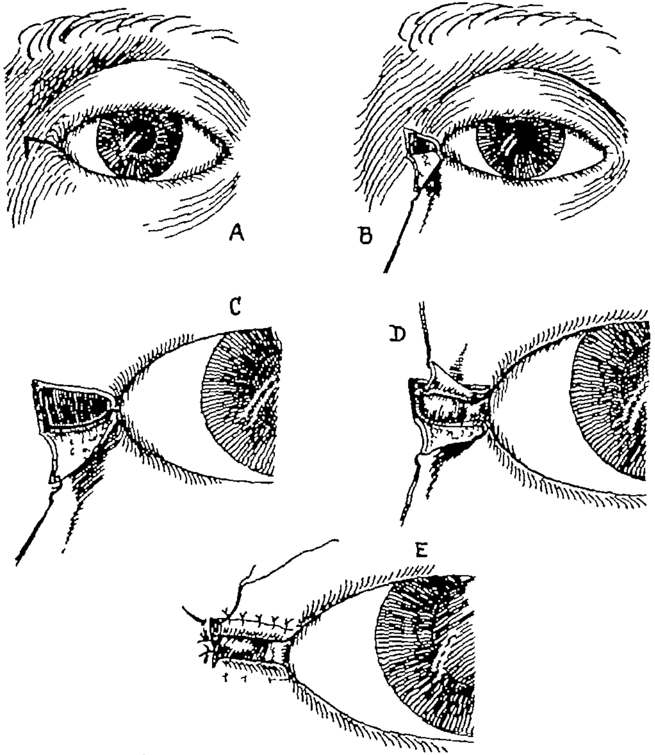

Fig 556. Canthoplasty for elongation of the palpebral fissure
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B. A flap is raised exposing the inner lining of the scarred area.
C. An oblique incision is made in the opposite direction to the preceding one outlining a second flap of conjunctiva.
D & E. Each flap is sutured over the raw area of the eyelid margin.

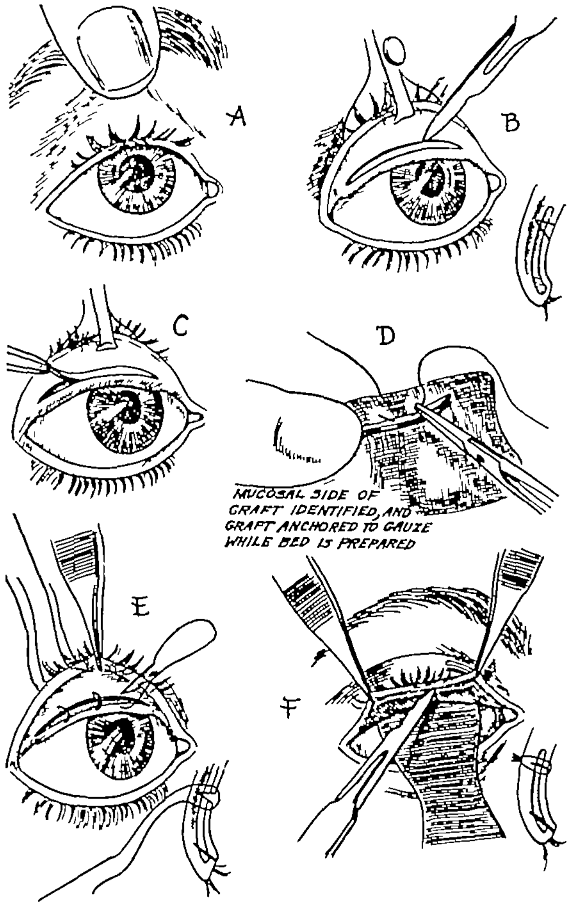


FIG. 557 The wedge graft operation for entropion

A. Typical cicatricial entropion with trichiasis.

B. The upper lid is everted. An elliptical segment of conjunctiva and tarsus is outlined

C. The composite graft of conjunctiva and tarsus is removed.

D. The composite graft of conjunctiva and tarsus is placed on moist saline gauze awaiting transplantation.

E. Approximation of the donor area of the composite graft. Note that the sutures have transpierced the full thickness of the lid and are tied on the skin surface

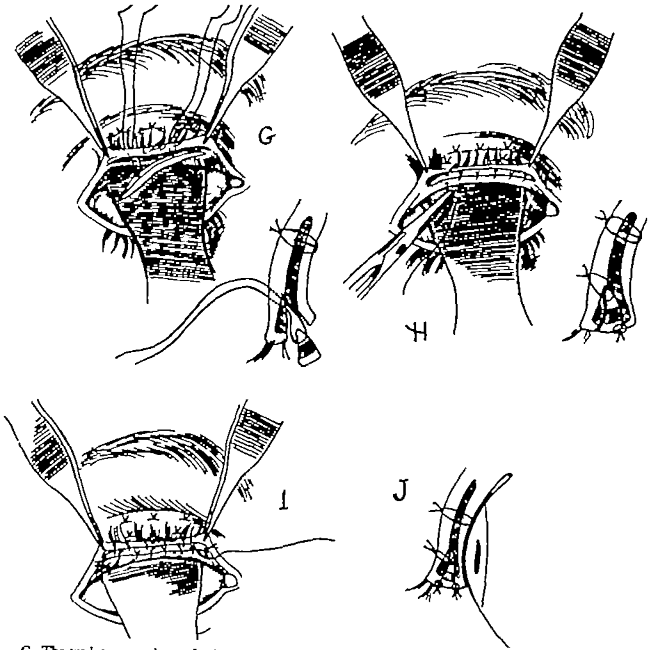
F. Incision at the white line of the upper lid splitting the free margin of the tarsus obliquely

located prior to incising to avoid cutting through the canaliculi

Entropion and Trichiasis

Cicatricial entropion or inversion of the lid differs from the spasmodic or degenerative type although traumatic entropion may involve both the upper and lower eyelids, the non-cicatricial type is usually limited to the lower eyelid.

Two types of cicatricial entropion occur The lid margin may be uninjured in the first type owing to the loss of conjunctiva however adhesions of the lid to the globe cause the inversion and the entropion is thus secondary to symblepharon Inversion and distortion of the lid margin is due to scarring in the second type. In this condition some of the eyelashes are turned in and trichiasis, contact of the eyelashes with the globe and cornea results. The eyelashes are normally inserted into the outer portion



G The wedge composite graft of conjunctiva and tarsus is placed in the incision line previously outlined along the margins of the lid.

H and I. Completion of suture of the edges of the graft to the edges of the defect.

J Cross section showing composite graft in position everting the hairbearing portion of the upper lid.

of the lid margin and sweep outward and upward Entropion is a turning in of the lid margin the eyelashes, in this process, may or may not contact the eyeball. Trichiasis may be present without true entropion whereas, entropion and trichiasis may be present together The direction of the base of the hair follicle and the shaft of the hair may be changed due to injury thus the eye lash instead of being directed outward may be directed inward resulting in trichiasis Trichiasis may also result from scarring of the inner aspect of the eyelid margin and is not an infrequent complication after reconstructive operations of the eyelids.

The treatment of entropion due to symblepharon requires the correction of the symblepharon in a first stage, by releasing the adhesions between the globe and the lid The treatment of symblepharon is considered later in this chapter Correction of entropion is necessary in a second stage if entropion persists after the relief of symblepharon

The Wedge Operation for Entropion

This operation utilizes the principle of introducing a composite wedge of tarsus and conjunctiva into an incision made along the inner margin of the lid in order to produce an eversion of the lid margin

The graft is removed from the inner aspect of the lid and includes conjunctiva and tarsus (Fig 557*A* to *D*) The donor area of the graft is sutured (Fig 557*E*) An incision is made at the inner aspect of the upper lid margin the incision extending upward at an angle of 45 degress to avoid injuring the base of the eyelash hair follicles (Fig 557*F*) The oblique incision permits rotation of the eyelid margin outward a triangular defect results from the rotation of the margin A wedge consisting of the composite graft of conjunctiva and tarsus is inserted in the incision at the lid margin to maintain the corrected position (Fig 557*G* to *J*)

Other Operations for Correction of Entropion

Entropion caused by small conjunctival defects inside the lid margin can be corrected by mobilizing a pedicle flap of conjunctiva from the opposing unaffected lid. The lids are held together by sutures for two weeks, at which time the sutures are removed and the conjunctival pedicle is sectioned.

An oval-shaped piece of skin is removed from the eyelid, fibers of the orbicularis oculi muscle are excised and the tarsus is thinned by shaving (Duverger and Velter 1926) (Fig 558). This operation is more suitable for the upper lid because of the larger size of the tarsus.

A modification of this procedure consists in removing a wedge of tarsus (Fig 559*A* *B*) the excised wedge does not extend through the entire thickness of the tarsus, a special suture (Fig 559*C* *D*) closes the triangular defect and rotates the lid margin outward

Another procedure is shown in Figure 560 The direction of the eyelashes can be changed by making an incision through the lid margin undermining the skin and separating the skin from the tarsus the skin carrying the eyelashes is then sutured to the conjunctiva at a lower level (Fig 560) the procedure is more suitable for the lower eyelid than for the upper

Isolated eyelashes, in contact with the bulbar conjunctiva often resist conservative treatment In such cases, the hair follicles of the offending eyelashes are destroyed either by electrolysis or excision of the tissue containing the eyelash

Operations for Trichiasis

Procedures for relief of trichiasis vary widely depending upon whether the misdirection of the eyelashes is confined to a small group of eyelashes, or whether a more extensive area is affected. The operation is analogous to that for entropion if the entire

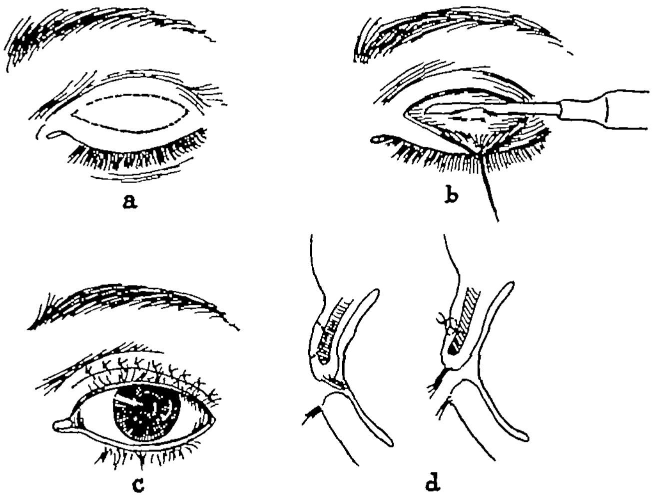


FIG 558 Drawings illustrating Duverger and Velter's operation for correcting entropion.

A. Site of skin excision.
B Area of tarsus shaved.
C. Skin sutured.
D Sagittal view showing amount of tissue excised and direction of hairs after suturing

lid is involved. Since entropion and trichiasis are often associated the procedures described for the relief of cicatricial entropion are also indicated for trichiasis.

When only a few eyelashes deviate from the normal direction and contact the cornea electrolysis or diathermy may suffice to destroy the hair follicles of the misdirected lashes. The needle is inserted along the shaft of the eyelash and a very weak current is employed for 1 or 2 seconds. The eyelash is then pulled out with a cilia forceps without removing the needle If the eyelash is not loosened the electric current is again applied for a longer time or with more intensity Failure to loosen the eyelash may be due to misdirection of the needle. Reinsertion of the needle may be necessary The lash can be removed by simple brushing with a cotton tipped applicator if the hair root is properly coagulated. This treatment has limitations because it is impossible to remove a number of eyelashes in close proximity to each other without risking necrosis of the eyelid margin In such cases it is advisable to complete electrolysis in multiple stages.

Surgery is the simplest method for the removal of misdirected eyelashes and is particularly applicable for the lower lid. The operation consists of excising a wedge of tissue containing the base of the hair follicles.

The position of the base of the eyelash hair follicles can be changed in some cases

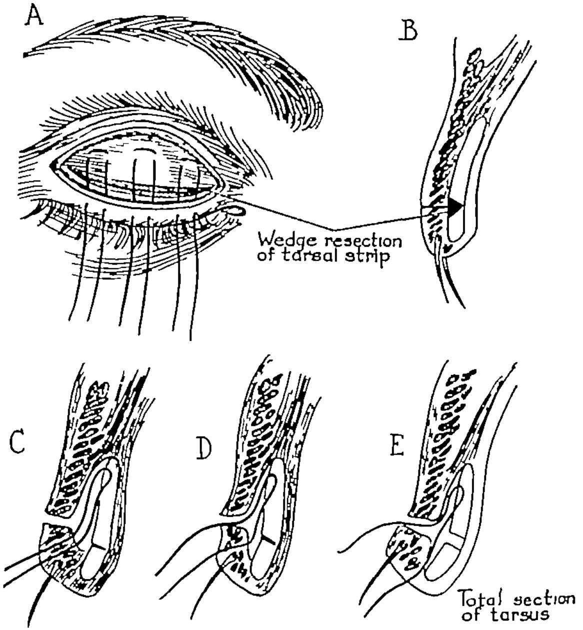


FIG 559 Operation for correction of entropion.

A and B. A partial thickness wedge of tarsus is removed

C and D A special suture placed to produce closure of the wedge in the tarsus and eversion of the lid margin.

E. An alternate technique consists in excising a full thickness section of the tarsus.

by moving them outward, by displacing the hairbearing portion of the eyelid outward and using a small conjunctival free graft to fill the resulting raw area.

Symblepharon

Chemical burns are a frequent cause of symblepharon a rare condition in flash and fire burns. The raw areas of the globe and the inner surface of the lid when healed, are fused by cicatricial bands. The entire inner surface of the lid may adhere to the globe in extensive symblepharon whereas in less extensive cases the adhesion may involve only a portion of the lid joined to the globe by a cicatricial band. Correction of the symblepharon may frequently be accomplished by Z flaps in this type of case (Fig 561). When the adhesion between the eyelid and the globe extends over a wider surface it is possible after cutting through the adhesion to undermine the adjacent con

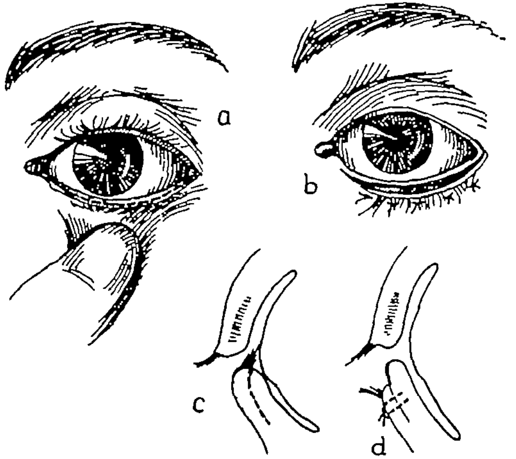


FIG 560. Entropion of lower lid corrected by splitting the lid at the margin (A, C) and moving the skin layer to a lower level (B D)

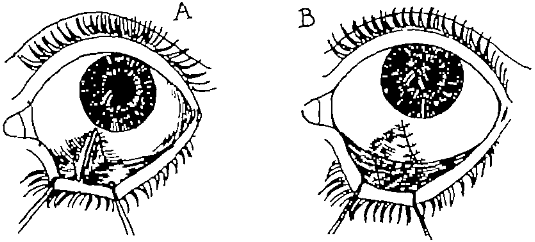
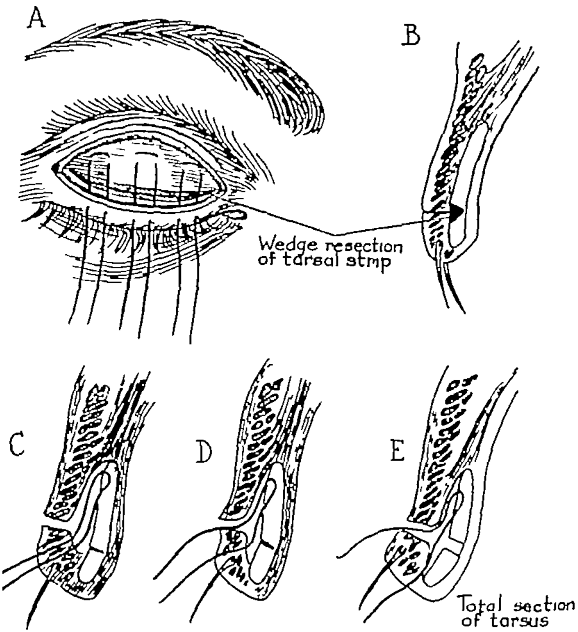


FIG 561 Z-plasty procedure for the correction of symblepharon

junctiva and to stretch it over the raw area of the lid, covering the scleral defect with a conjunctival graft (Fig 562).

Conjunctival Flap from the Opposing Eyelid

The conjunctiva of the upper lid is a source of supply for extensive cases of symblepharon of the lower lid The technique consists of cutting through adhesions to free the lid from the globe (Fig 563*A* *B*) Following this procedure a horizontal incision is made through the conjunctiva just above the upper lid margin. The conjunctiva of the upper lid is undermined freely advanced and held in position in the depth



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A and B. A partial thickness wedge of tarsus is removed.

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E. An alternate technique consists in excising a full thickness section of the tarsus.

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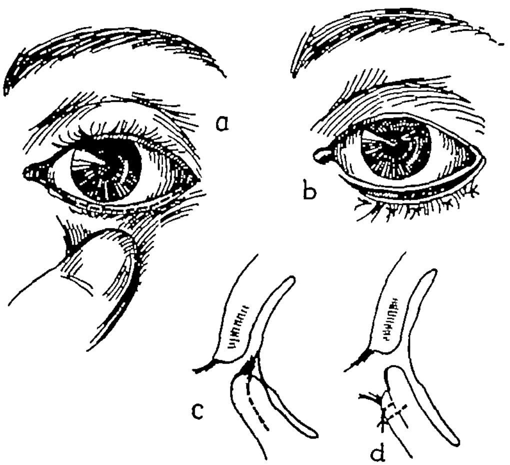

FIG 560. Entropion of lower lid corrected by splitting the lid at the margin (A, C) and moving the skin layer to a lower level (B, D)

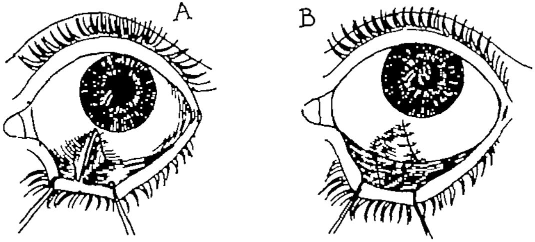

FIG 561 Z plasty procedure for the correction of symblepharon

junctiva and to stretch it over the raw area of the lid, covering the scleral defect with a conjunctival graft (Fig 562)

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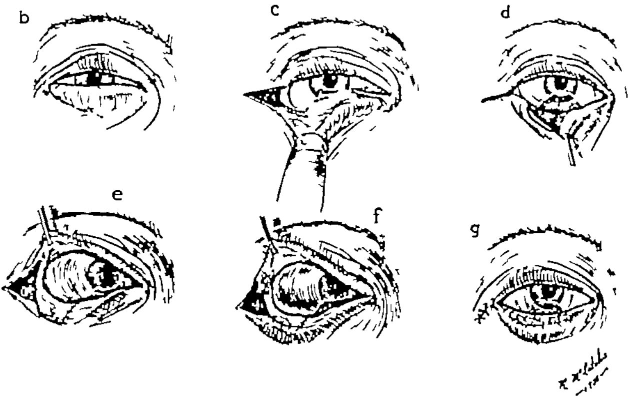


FIG 562. Correction of symblepharon with entropion

B Drawing showing symblepharon associated with entropion.
C Shows the adhesion between bulbar and lid conjunctivae
D The lid is freed from the eyeball, leaving a raw area on each structure
E A flap of conjunctiva from upper lid is brought down to cover the defect of the lower lid.
F The secondary defect closed by direct approximation
G The skin incision is closed. The raw area on the eyeball is allowed to epithelize spontaneously

of the fornix by a mattress suture with the ends brought out through the skin (Fig 563C) the lid margins are separated later (Fig 563D F)

Conjunctival or Mucosal Grafts

A small conjunctival defect can be repaired by a free graft of conjunctiva removed *from the opposing eyelid of the same* eye or from an eyelid of the other eye mucosa is obtained from the buccal wall of the oral cavity when a larger mucosal surface is required.

Transplantation of a Thiersch graft although a simpler method should not be employed since friction of the dermo-epidermic graft against the eyeball and cornea causes irritation leading to keratoconjunctivitis or even more serious sequelae

Sections of mucosa as large as 1¼ by 5 cm., are removed from the buccal wall (Fig 564) The tissue is taken preferably from the vicinity of the lower buccal sulcus the looseness and elasticity of the mucosa in this region permits the closing of the donor area by direct approximation of the borders. The graft is spread over a wet-gloved finger and the submucosal tissue is removed with scissors. A split thickness mucosal graft may *also be removed by means of* Castroviejo s electric dermatome (see Fig 161 Chapter 18)

The technique shown in Figure 565 may be employed in moderately extensive symblepharon a conjunctival graft is employed for the scleral defect In extensive symblepharon a wide surface of the conjunctival surfaces of the eyelid and of the sclera must be covered and the conjunctival cul-de-sac re-established *(Fig 566) The* scar tissue is resected after obtaining the graft of oral mucosa and the fornix is extended to the

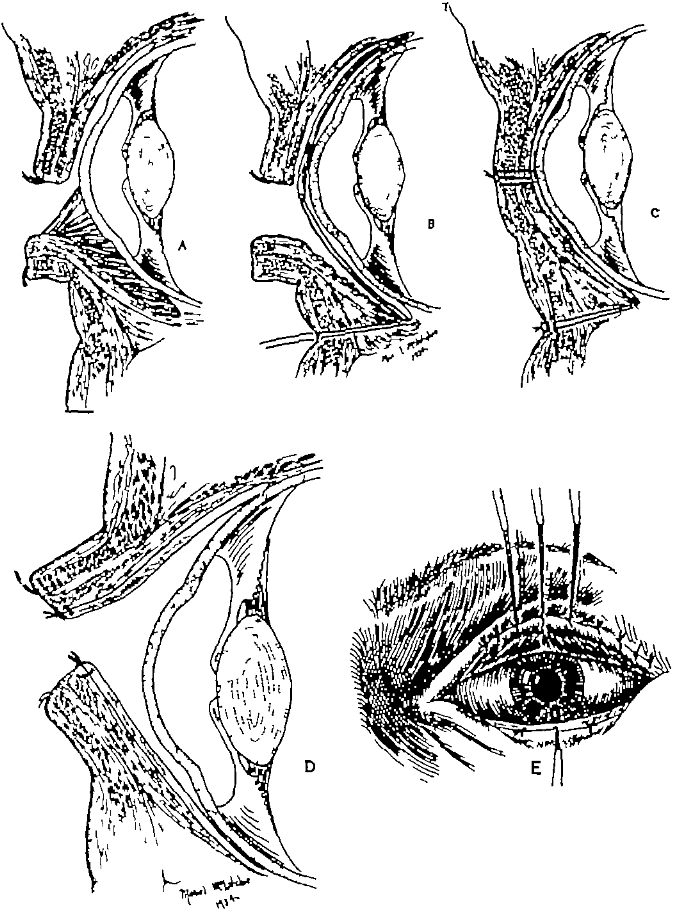


FIG 563 Drawings illustrating an operation for symblepharon

A. The lower lid adheres to the eyeball

B. The adhesions between the lower lid and the eyeball have been cut through. The conjunctiva lining the upper lid is freed from the tarsus and a mattress suture is placed at its lower edge. The suture is then passed through the cul-de-sac and brought out through the lower lid.

C. The conjunctival flap from the upper lid is brought down into the lower fornix, held by the mattress suture. A tarsorraphy is done.

D In a later stage the lids are separated and the conjunctiva is cut through.

E. Result obtained.

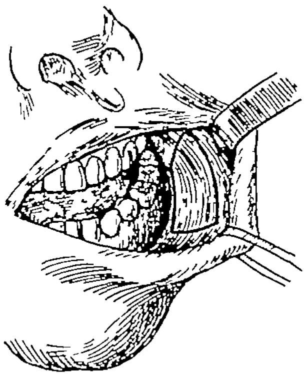


Fig 564 Area of buccal mucosa from which mucous membrane graft may be transplanted to the orbit.

periosteum of the infraorbital margin (Fig 566*A*) The graft is then sutured to the edges of the conjunctival and scleral defect (Fig 566*B*)

The lower margin of the graft is anchored with through and through sutures to assure *the depth of the conjunctival fornix (Fig 566C D)* The infraorbital margin should be exposed and the graft applied against it in order to further assure the depth of the conjunctival cul-de-sac. An external pressure dressing is then applied. A case of symblepharon is shown in Figure 567

Full Thickness Loss of the Eyelid

Partial or complete full thickness loss of eyelid tissue varies with etiological factors. total loss of the lid is usually accompanied by loss of the eyeball in traumatic cases, complete loss of the lid follows resection for malignancy a section of the lid is missing in congenital coloboma The treatment of such deformities has established principles of reconstructive surgery which are employed in defects due to trauma.

Partial Loss of the Eyelid

The following principles are employed in planning the operative procedure for reconstruction following partial full thickness loss of the eyelid

1 The conjunctiva of the unaffected eyelid is suitable and preferable to replace the inner lining

2 Eyelid tissue is used whenever possible

LATERAL ADVANCEMENT FLAP The lateral *portion of the eyelid is advanced toward the* nasal side The outline of such a flap differs

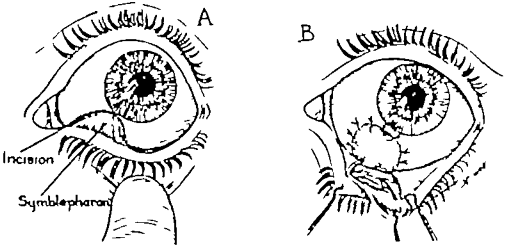


Fig 565. Correction of symblepharon

A Freeing of the adhesion between the eyelid and the eyeball The scarred tissue over the sclera is employed to provide lining for the lower lid.

B The scleral defect is covered by means of a conjunctival graft.

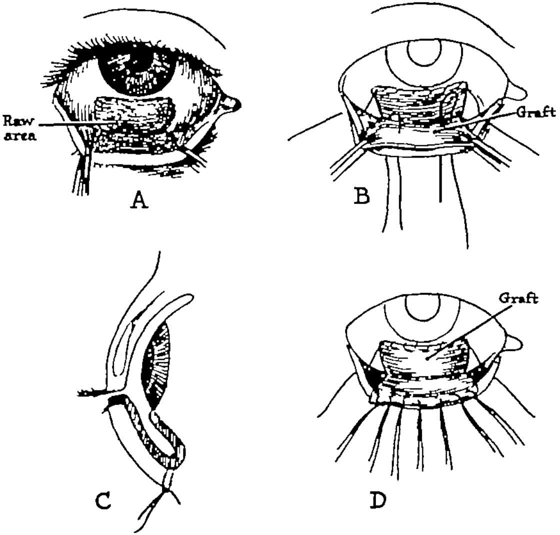


Fig 566 Treatment of symblepharon

A. Raw area after freeing adhesions.

B. Mucous membrane graft sutured to edge of eyelid. Anchoring sutures placed in graft for attachment of graft in cul-de-sac.

C and D Anchoring sutures brought out through skin after being passed through periosteum of infra orbital rim.

Fig 567 Symblepharon

A. Photograph showing medial symblepharon resulting from an acid burn

B. Result obtained following operation

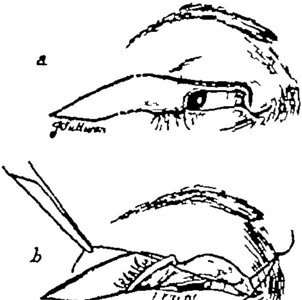


FIG 568 Full thickness loss of eyelid tissue. Repair by island flap

A. Incision of flap permitting the advancement of the lateral portion of the upper lid

B. The edges of the defect are approximated by sutures

C. Lid reconstructed after advancement of the lateral portion

D. The operation has been completed.

in each case the procedures usually employed are shown in Figure 568 and further modifications of these procedures are illustrated in Figure 569

A horizontal incision beginning at the outer canthus is extended posteriorly for approximately 2.5 cm. (Fig 569 A) The skin below the incision and also that of the lid is undermined freely The conjunctiva above the outer canthus is also undermined, and if necessary an incision is made in the upper lid conjunctiva to gain necessary relaxation This procedure ordinarily provides sufficient skin and conjunctiva to close a small defect (Fig 569B C) If the skin is under considerable tension however an additional short parallel incision is extended from the outer end of the zygomatic incision line as far forward as necessary to gain relaxation of the lid flap without hampering the blood supply The remaining section of the lid is shifted medially (Fig 569D F), and the defect is filled by the advancement of the lateral portion of the lid If the conjunctiva of the outer canthus cannot be extended to form the inner lining a conjunctival flap is borrowed from the unaffected lid. The secondary defect is closed by direct approximation or by mobilization of a local flap

TARSOCONJUNCTIVAL FLAP FROM THE OPPOSING EYELID (Landolt 1881 Kollner and Hethey 1911 Hughes, 1937) A quadrangular flap of conjunctiva and tarsus is cut in the opposing lid leaving the margin of the lid intact the flap is advanced and sutured into the defect (Fig 570). The skin covering is obtained by a free full thickness graft of eyelid or retroauricular skin. The lids are connected by a tarsorraphy which is maintained for a period of at least two months. Eyelashes may be provided by a free transplant from the eyebrow (Fig 571). The tarsoconjunctival bridge is severed at a later date

ESTLANDER TYPE OPERATION If a considerable part of the lid is destroyed a section of the unaffected eyelid is transposed in a procedure similar to the Estlander operation a method successfully employed to repair defects of the lips. A semicurved rectangular incision is made through the outer border of the unaffected eyelid if the outer section of the lid is destroyed the flap thus created

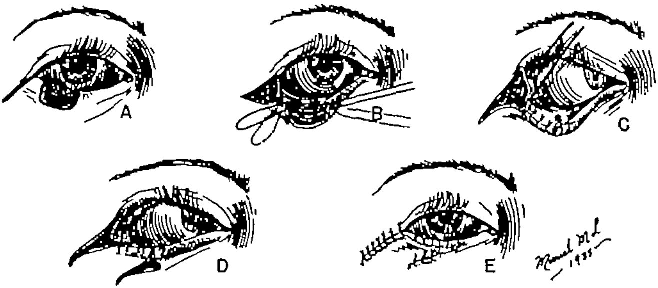


Fig 569 Full thickness loss of eyelid tissue. Repair by advancement flap

A. Illustrating defect of the lower lid Incision outlining advancement flap.
B. Approximation of the edges of the defect.
C. Closure of conjunctival defect.
D The conjunctiva is sutured to the skin forming a new lateral canthus.
E. The operation is completed.

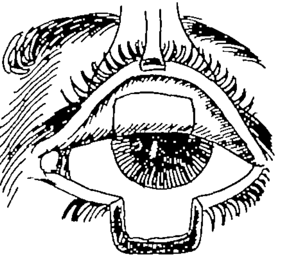


Fig 570. Tarsoconjunctival flap from the opposing lid to repair a median defect of the lower lid (After Hethey and Köllner 1911)

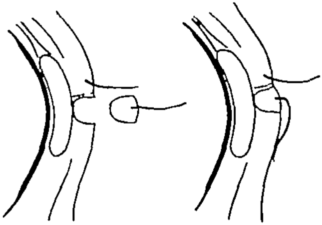


Fig 571 Hair-bearing eyebrow graft to restore the eyelashes in a reconstructed lid.

is carefully sutured into the opposite eyelid defect (Fig 572) In a second operation about two weeks later a horizontal incision is made from the outer canthus toward the zygoma to enlarge the palpebral fissure. Enough mucosa is usually available to make this procedure possible such an operation, however although effective in providing protection to the ocular globe may not restore the desired appearance

COMPOSITE GRAFTS OF EYELID TISSUE. Full thickness sections of eyelid tissue may be removed and transplanted as composite grafts to repair a full thickness defect of the opposite lid. A wedge shaped section of tissue 1 cm. in width at its base is removed from the middle third of the lid and transplanted into the defect in the opposite lid.

Such composite grafts receive their blood supply from the junction line between the edges of the graft and the lid defect the size of the transplant being limited because of the small area of contact with the host tissues (see Chapter 22) Careful suturing ap-

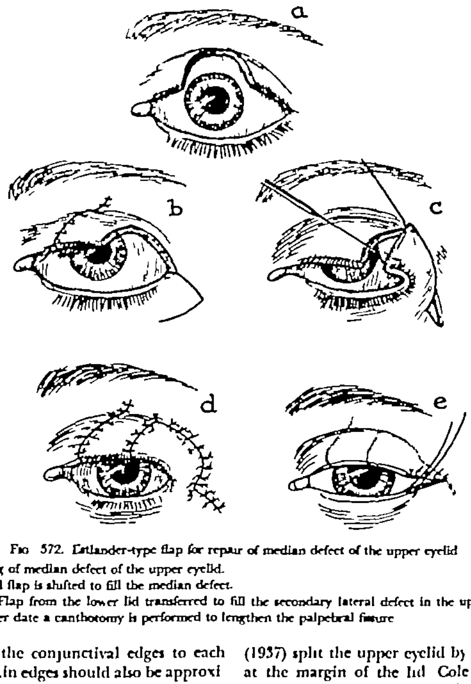


Fig 572. Estlander-type flap for repair of median defect of the upper eyelid

A. Drawing of median defect of the upper eyelid.

B. A lateral flap is shifted to fill the median defect.

C and D Flap from the lower lid transferred to fill the secondary lateral defect in the upper lid.

E. At a later date a canthotomy is performed to lengthen the palpebral fissure

proximates the conjunctival edges to each other: the skin edges should also be approximated.

Total Loss of the Eyelid

The principle of utilizing tissue from the unaffected upper eyelid was emphasized by Dupuy Dutemps (1927) Hughes (1937) developed an operation independently which embodies procedures described previously by Landolt (1881) Köllner and Hessberg (1911) and Dupuy Dutemps (1927).

A modification of the Landolt Hughes operation restores the upper or lower lid satisfactorily (Figs. 573 and 574) Hughes (1937) split the upper eyelid by an incision at the margin of the lid Cole (1937) has employed a conjunctival incision which extends through the tarsus above the level of the lid margin This modification preserves a rim of tarsus along the edge of the lid and avoids distortion of the upper eyelid. After excision of scar tissue along the rim of the defective lid (Fig 573A B) a horizontal incision is made 2 to 3 mm above the margin of the upper lid through the tarsus the upper lid is then split into an outer and inner layer (Fig 573C D F) The outer layer consists of skin lid margin and orbicularis oculi muscle the inner layer is

composed of conjunctiva and the greater part of the tarsus, with some levator muscle fibers attached to its upper portion.

The margin of the remnant of the lower lid and the inner layer of the upper lid are freshened and attached to each other with a continuous buried suture (Fig 573E, F) The skin layer of the upper lid is anchored to the inner layer at a level about midway between the upper and lower borders of the tarsus (Fig 573G) The remaining raw area is covered by a full thickness postauricular skin graft (Fig 573H I)

An eyebrow graft bearing a line of hairs may be implanted in the lower lid about six weeks later (Fig 571) The lids are opened six or seven weeks following this procedure by a transverse incision between the two rows of hairs (Fig 573J K)

Figures 575 and 576 show examples of reconstruction of the upper lid by a reverse procedure, employing the lower lid as donor

The Tarsoconjunctival Flap in Severe Burn Ectropion

This technique (Converse and Smith 1958) is employed in intractable severe burn ectropion deformity in which a part of the eyelid margins has been destroyed (Figs. 577 and 578) a condition usually observed in patients with severe burn ectropion who have been unsuccessfully or only partially successfully skin grafted in the early stages.

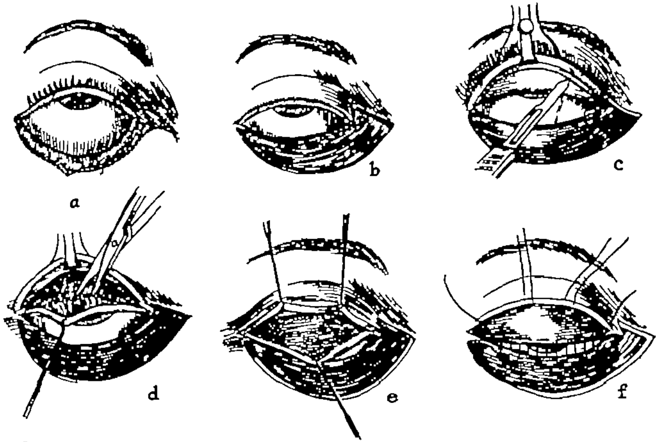


FIG 573 Reconstruction of the lower eyelid by a modification of the Hughes-Landolt procedure.

A. Outline of first incision to free the remaining conjunctiva.

B. Resulting defect.

C. Line of incision for the splitting of the upper eyelid.

D Splitting of the upper eyelid into two layers. An outer layer of skin and muscle and an inner layer comprising the tarsus and conjunctiva.

E. The tarsoconjunctival layer is retracted downward.

F The free margin of the tarsoconjunctival layer is sutured to the rim of the remaining conjunctiva in the lower lid by a continuous end-on suture.

(See continuation in next figure.)

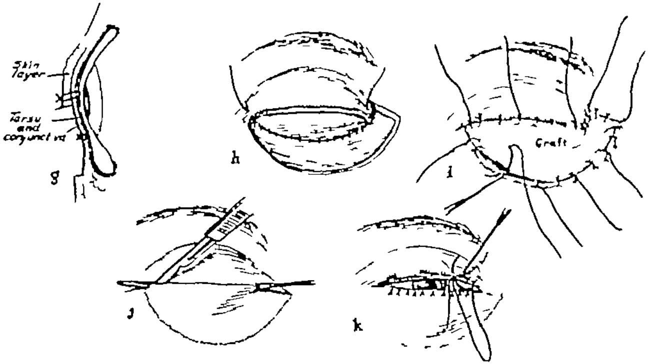


FIG. 578—*Continued*

G Diagram showing tarsoconjunctival flap sutured to conjunctiva of the lower lid. Note also the fixation of the skin of the upper lid to the tarsoconjunctival layer by means of mattress sutures.

H Appearance of defect after reconstruction of the inner layer

I *The defect is covered by a free full thickness retroauricular graft.*

J In a later stage the lids are separated by incising over a grooved director passed through a small opening at medial end of the palpebral fissure and brought out near the lateral canthus.

K. The free margins of the lids are completed by suturing skin to conjunctiva Support of the lower lid is assured by the presence of a portion of the superior tarsus

The deformity in this type of case (Fig 578) is characterized by ectropion and short lids and forward displacement of the medial canthus and medial third of the eyelids the eyelashes have been destroyed

Incisions are made at the lid margin of both upper and lower eyelids along the entire length of the margins except for a few millimeters in the area of the medial and lateral canthus (Fig 577*A*) The tarsoconjunctival layer is separated from the superficial soft tissue which includes orbicularis oculi muscle fibers and skin (Fig 577*B* *C*). In the lower eyelid the palpebral fibers of the orbicularis oculi musculature are included in the tarsoconjunctival flap (Fig 577*C*) these additional muscle fibers are *necessary to support the reconstructed lower eyelid* The dissection in the lower lid therefore extends along a plane between the skin and the orbicularis oculi muscle fibers. The scar tissue medial to the inner canthus over the frontal process of the maxilla must be resected to permit recession of the medial canthus to its normal position this procedure is similar to the one described previously (see Fig 555) The margins of the tarsoconjunctival flaps are excised and approximated by a to-and fro continuous buried 5-0 Nylon suture (Fig 577*D* *F*) the ends of the suture extend out through the skin a short distance from each canthus. The remnants of the scarred outer layer of the eyelid margins are resected (Fig 577*D*). The skin edges are widely retracted revealing a raw area over the tarsoconjunctival layer which is ready to be grafted the skin edges retract readily because of the eyelid skin deficiency The raw area represented by the outer surface of the tarsoconjunctival layer is covered

by a split thickness graft which is maintained on a dental compound mold (Fig 577*F* and *G*)

In a later stage six weeks to two months after the first operation an incision is made through the tarsoconjunctival layer to separate the upper and lower eyelids (Fig 577*H*) The raw surface along the margins of the lids is eliminated by suturing the outer skin to the inner conjunctiva Figure 578 illustrates the result obtained by this technique the intermediary stage prior to the separation of the lids is shown in Figure 579

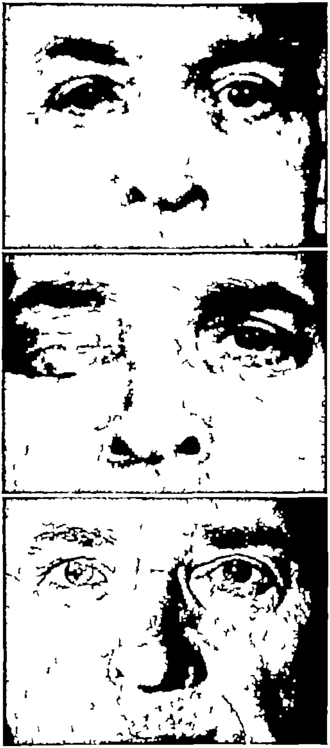
Reconstruction of the Lateral Portion of the Upper and Lower Eyelids (Smith, 1953)

This technique, employed for reconstruction following excision for malignant disease, is also applicable to defects due to injury The technique is demonstrated in Figure 580

Resurfacing the newly constructed internal layer of the lower lid is facilitated by excising a small Bürow triangle of skin at the inferomedial angle of the wound to facilitate advancement of a skin flap (Fig 580*K*) This advancement flap is feasible in older patients because of the laxity of the tissues a split thickness graft may be a preferable method in younger patients. Closure is effected with fine interrupted sutures (Fig 580*L*) the free end of the continuous nylon suture which is to be removed later from the tarsoconjunctival layer is then tightened and locked on the surface of the skin flap

In a later stage, a cilia graft from the eyebrow improves the appearance of the new lid. A free graft of skin from the brow about four hairs in width is anchored with fine sutures in the prepared bed along the margin of the healed skin flap (Fig 580*N* *O* *P*)

The bed is prepared by making a horizontal I-shaped incision at the proper level (Fig 580*N*) the two small flaps thus created



A

B

C

FIG 574 Reconstruction for complete loss of the lower lid.

A. Photograph showing loss of the right lower lid.

B. Appearance after the upper tarsus has been drawn downward and the covering of the lower lid supplied by a skin graft.

C. Photograph showing reconstruction completed according to technique illustrated in Figure 573

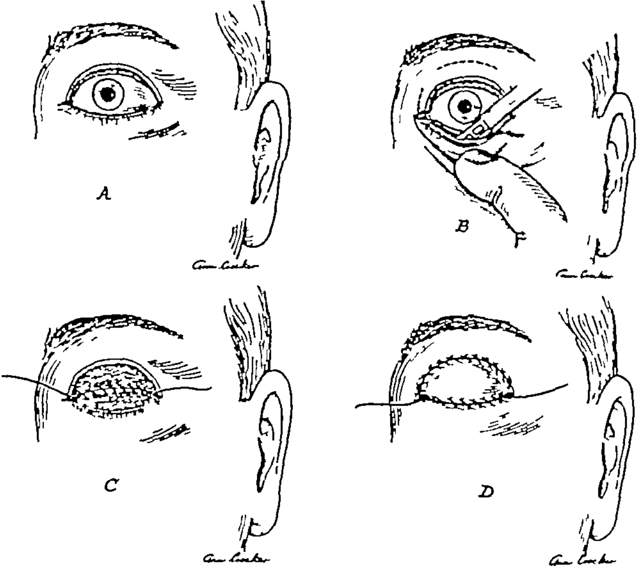


Fig 573

A. Diagram showing subtotal loss of the upper eyelid

B Tarsoconjunctival flap prepared in the lower eyelid and also in the upper eyelid.

C. Upper and lower tarsoconjunctival flaps brought together with continuous suture which is allowed to protrude at each end

D Postauricular full thickness skin graft sutured over the raw area Note loose ends of continuous suture maintaining the tarsoconjunctival flaps in apposition

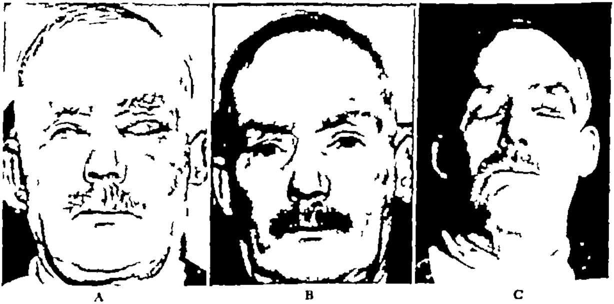


Fig 574

A Photograph showing upper eyelid reconstructed according to technique illustrated in Figure 73

B Appearance of left upper eyelid after separation of the eyelids

C Photograph with eye closed Patient had full control of the upper lid

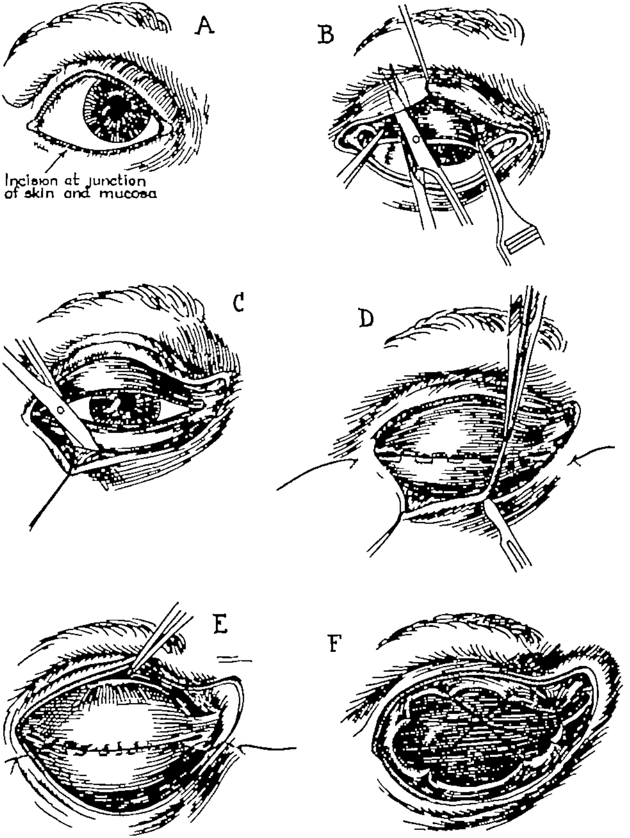


FIG 577 The tarsoconjunctival flap in severe burn ectropion

A. Outline of incision made along the entire margin of both upper and lower eyelids.

B. Separation of the tarsoconjunctival flap of the upper lid.

C. Separation of the tarsoconjunctival flap of the lower lid.

D Suture of the tarsoconjunctival flaps of upper and lower eyelids. Excision of the eyelid margin along the edge of the defect.

E. The skin of the eyelids is retracted in every direction in order to increase the raw surface. Instrument is pointing to the insertion of the levator on the superior tarsus.

F Dental compound mold carrying split thickness skin graft (outlay technique)

(*See continuation in next figure*)

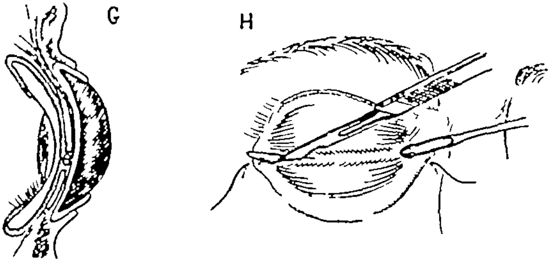


FIG 577 (*Continued*)

G Cross section of the semiburied mold technique introducing an excess of skin graft (outlay technique)
H In a second stage the upper and lower eyelids are separated by an incision.
(Figures 577 to 579 from J M Converse and B Smith, Plast. & Reconstruct. Surg., 23 21 1959)

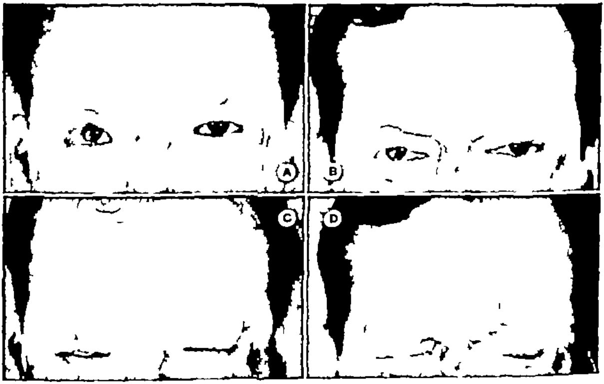


FIG 578 Ectropion and distortion of the eyelids following burns treated by the method outlined in Figure 577

A Ectropion with medial canthal deformity
B Postoperative view
C Preoperative condition. Occlusion of the eyelid is incomplete
D Postoperative result Eyelid closure is satisfactory

provide a covering for the raw edges of the cilia graft. The eyebrow wound is closed by fine interrupted sutures. The sutures in both eyebrow and graft are removed at the end of five days.

The third stage of the procedure is done after the cilia graft has been in place for six weeks. A grooved director is placed within the conjunctival sac behind the interpalpebral adhesion (Fig 580Q) and a scalpel is employed to open the interpalpebral fissure to its proper length The raw area at the

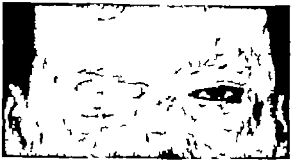


FIG 579 Intermediary stage in technique illustrated in Figure 577 The eyelids have been joined by a tarsoconjunctival flap and covered by a split thickness skin graft applied by the outlay technique (see Figure 577 E to G)

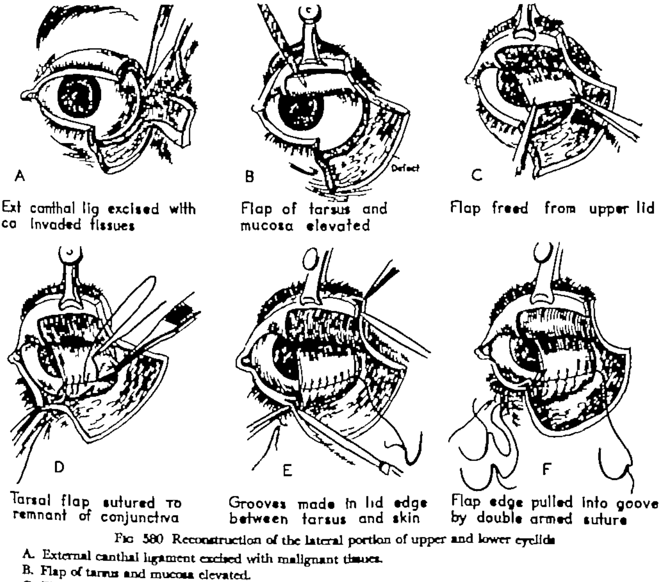


FIG 580 Reconstruction of the lateral portion of upper and lower eyelids

A. External canthal ligament excised with malignant tissues.
B. Flap of tarsus and mucosa elevated.
C. Flap freed from upper lid.
D Tarsal flap sutured to remnant of conjunctiva.
E. Grooves made in lid edges between tarsus and skin.
F Flap edge pulled into groove by double-armed suture.

(See continuation in next figure)

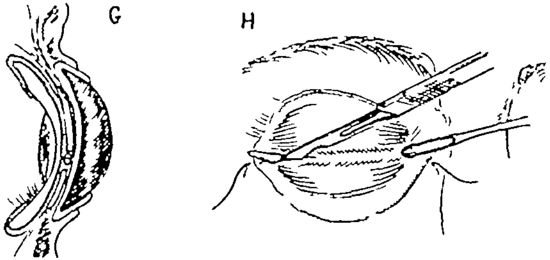


Fig. 577 (*Continued*)

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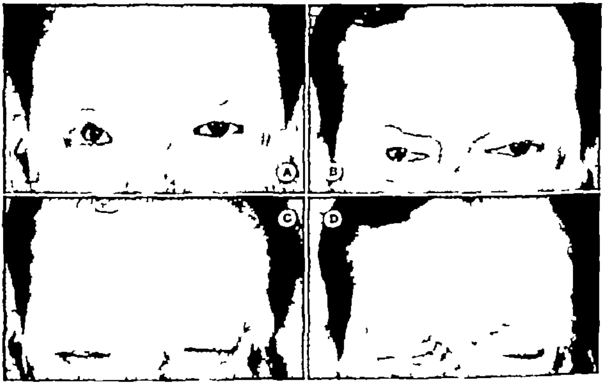

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C Preoperative condition Occlusion of the eyelids is incomplete

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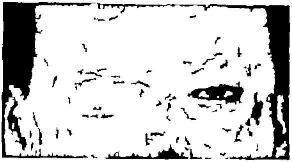

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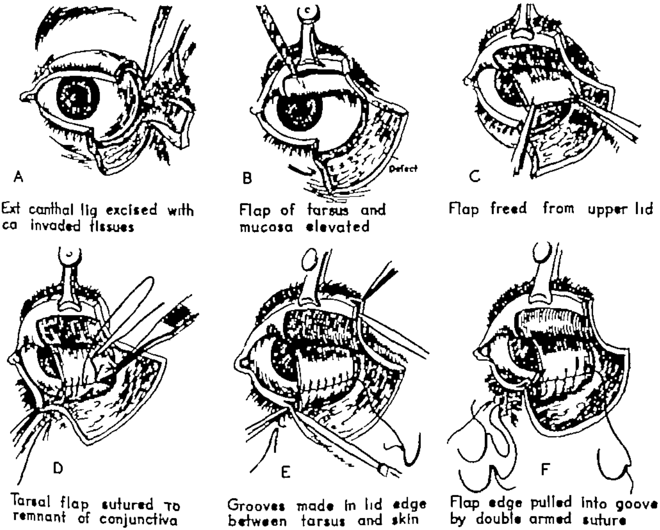

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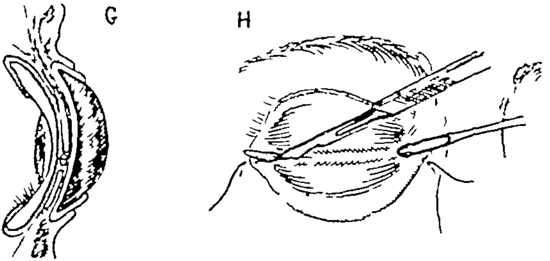
(See continuation in next figure)



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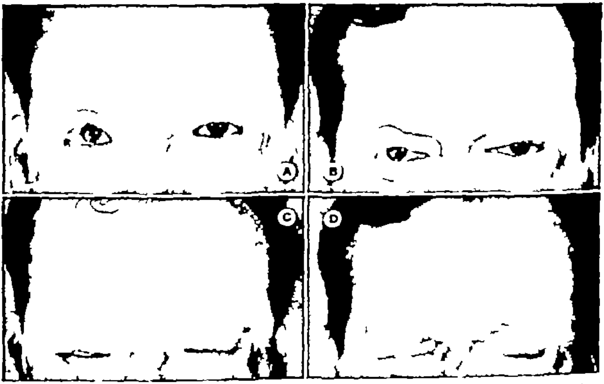

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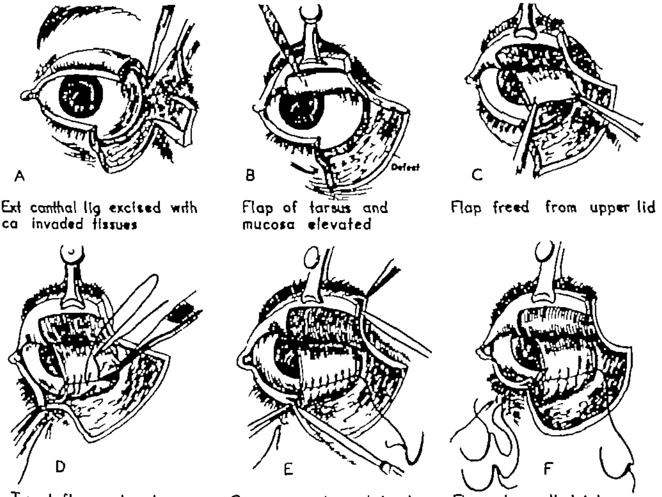

FIG 580 Reconstruction of the lateral portion of upper and lower eyelids

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(*See continuation in next figure*)

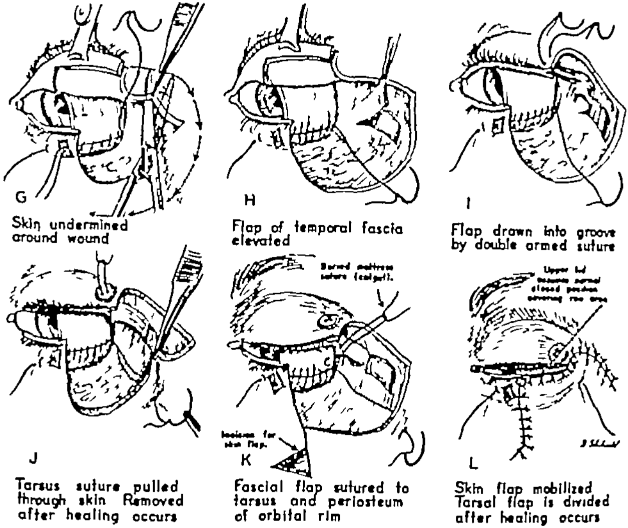

Fig 580 (*Continued*)

G Skin undermined around wound.
H Flap of temporal fascia elevated.
I Flap drawn into groove by double armed suture.
J Tarsus suture pulled through skin. Removed after healing occurs.
K. Fascial flap sutured to tarsus and periosteum of orbital rim.
L. Skin flap mobilized. Tarsal flap is divided after healing occurs.

(*See continuation in next figure*)

temporal extremity of the canthus is carefully sutured with fine sutures to prevent closure of the lateral canthal angle (Fig 580*P*)

Traumatic Ptosis of the Upper Eyelid

It is important to determine the cause of traumatic ptosis of the upper eyelid Is it due to section of the levator palpebrae superioris muscle or to paralysis of the levator muscle due to third nerve injury? In compound fractures involving the roof of the orbit and the supraorbital region detached fragments of bone may extend downward, pressing on the levator palpebrae superioris and interfering with the raising of the lid. Some severe injuries with loss of bone in the region of the orbital roof may result in ptosis by herniation of the brain down over the eyeball In other injuries a loss of bone in the region of the floor of the frontal sinus with infection and hypertrophic granulations in the frontal sinus may cause a tumor like mass to press downward on the upper eyelid also causing ptosis.

If the diagnosis of traumatic section of

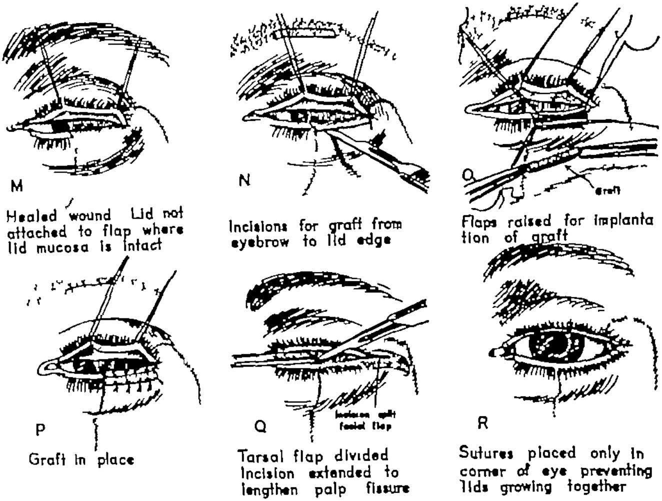

FIG 580. (*Continued*)

M. Healed wound. Lid not attached to flap where lid mucosa is intact.
N Incisions for graft from eyebrow to lid edge.
O Flaps raised for implantation of graft.
P Graft in place.
Q Tarsal flap divided. Incision extended to lengthen palpebral fissure.
R. Sutures placed only in corner of eye, preventing lids growing together
(From B. Smith, Tr Am. Acad. Ophth. and Otol., 157 738, 1953)

the levator palpebrae superioris is verified efforts should be made to repair the muscle (Fig 581). Failure to resuture the levator muscle is usually due to an inability to locate the proximal end. The levator muscle is a Y-shaped structure whose extensions are attached to the medial and lateral palpebral ligaments (see Fig 522) The muscle is usually not completely sectioned and it is possible by exposing the attachments of the levator to one of the palpebral ligaments to follow the aponeurosis upward, dissecting the muscle carefully until one of its intact edges is identified the dissection is then continued across the muscle and downward to the line of section The proximal and distal portions of the sectioned muscle may then be sutured

Various procedures have been recommended to correct the condition when suture is not possible. These include shortening the upper lid by excising a portion of the tarsus shortening the levator muscle attaching the superior rectus muscle to the eyelid connecting the eyelid to the frontalis muscle

Excision of a portion of the tarsus with the excess skin and conjunctiva (de Grandmont, 1891) is rarely applicable for correction of traumatic ptosis the drooping of the eyelid usually being due to section of the levator muscle. Advancement of the levator muscle

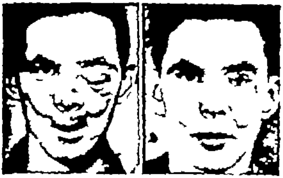

FIG 581 Repair of traumatic section of the levator palpebrae superioris muscle

A Appearance of patient after automobile accident in which the tissues of both cheeks and the nose were raised as a flap after being ripped from the skeletal framework of the face The penetrating wound in the left orbit severed the levator muscle

B Result obtained following secondary suture of the severed ends of the left levator palpebrae superioris muscle

(von Blaskovics, 1929) is also not always a practicable procedure The Motais (1903) technique which consists of splitting the superior rectus muscle and detaching one end of part of the tendon and reattaching it to the eyeball can be employed to replace the action of the levator This method however may result in diplopia because the superior rectus is weakened. Absence of binocular vision in the congenital type of ptosis is frequently due to the presence of associated extraocular muscle anomalies. Upsetting the vertical muscle balance is not a consideration in congenital ptosis. In traumatic ptosis, however the patient usually has normal binocular vision and any disturbance of the vertical muscle balance by such a procedure as advancement of the superior rectus muscle may result in diplopia the advancement of the superior rectus is not employed for this reason Possible changes in the extraocular muscle balance must be considered for there is a greater range in convergence and divergence horizontally between the two eyes than vertically the normal horizontal fusion range is in the order of thirty diopters, while the vertical range is limited to less than diopters

The lid can be suspended from the frontalis muscle with fascia lata if the continuity of the levator cannot be restored. An incision is made parallel to and just above the free border of the upper lid and the tarsus is exposed (Fig 582A B). Fascia lata approximately 2.5 cm square is divided forming three extensions from the common base which is then attached to the entire length of the tarsus by means of fine sutures (Fig 582C)

The three separated strips are pulled upward through small incisions established laterally centrally and medially above the eyebrow the lid is pulled upward evenly to the desired level by means of these multiple strips notching of the lid margin which is a frequent result when but one strip of fascia is employed is thus avoided. The fascial slings are anchored to the frontalis muscle by buried sutures placed at the level of the incisions. The ends of the fascia are extended upward beneath the skin by means of mattress sutures brought out through the skin and tied over the gauze (Fig 582D). The incisions in the lid and above the eyebrow are closed the mattress sutures are withdrawn at a later date Figure 583 illustrates complete ptosis of the upper lid and the result following surgical correction (Kazanjian 1939)

Correction of ptosis may also be obtained by a single buried suture which anchors the lid to the frontalis muscle (Friedenwald and Guyton 1948) We employ this technique modified by Smith and Pang (1955), using fascia lata for the suspension suture Narrow strips of fascia lata are obtained by the stripper technique described in Chapter 19 (see Figure 472)

Two stab incisions are made through the skin of the upper lid 2 mm above the lid margin and about 2 cm apart and are placed symmetrically about 7 mm from the medial and lateral canthus respectively

a Berbecker (size 8) needle or a fine needle a strip of fascia lata is a horizontal mattress suture

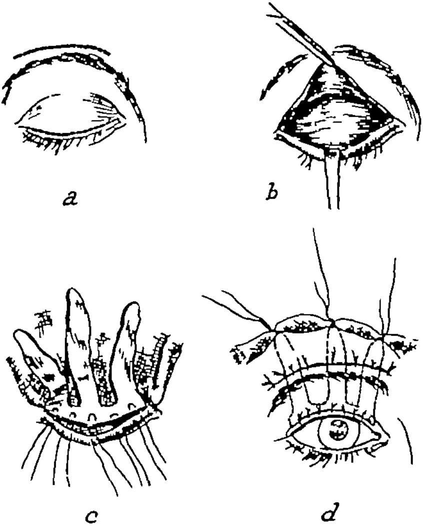

Fig 582 Fascia lata suspension in traumatic ptosis of the eyelid

A. Drawing illustrating incisions for the operation.
B. Exposure of the tarsus.
C. Tongue-shaped piece of fascia lata sutured along its base to the tarsus.
D The fascial strips are pulled upward and held anchored

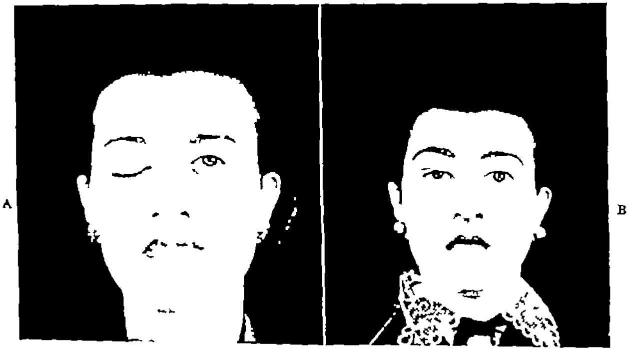

Fig 583 Traumatic ptosis of the upper lid

A. Photograph showing complete ptosis of the right upper lid resulting from severance of the levator in automobile accident.

B. Photograph after operation for fascia lata suspension, as illustrated in Figure 582

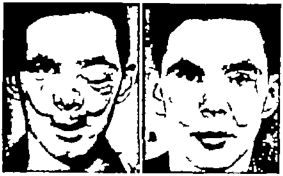

FIG 581 Repair of traumatic section of the levator palpebrae superioris muscle.

A. Appearance of patient after automobile accident in which the tissues of both cheeks and the nose were raised as a flap after being ripped from the skeletal framework of the face. The penetrating wound in the left orbit severed the levator muscle.

B. Result obtained following secondary suture of the severed ends of the left levator palpebrae superioris muscle.

(von Blaskovics, 1929) is also not always a practicable procedure. The Motais (1903) technique which consists of splitting the superior rectus muscle and detaching one end of part of the tendon and reattaching it to the eyeball can be employed to replace the action of the levator This method, however may result in diplopia because the superior rectus is weakened. Absence of binocular vision in the congenital type of ptosis is frequently due to the presence of associated extraocular muscle anomalies. Upsetting the vertical muscle balance is not a consideration in congenital ptosis. In traumatic ptosis, however the patient usually has normal binocular vision and any disturbance of the vertical muscle balance by such a procedure as advancement of the superior rectus muscle may result in diplopia the advancement of the superior rectus is not employed for this reason. Possible changes in the extraocular muscle balance must be considered for there is a greater range in convergence and divergence horizontally between the two eyes than vertically the normal horizontal fusion range is in the order of thirty diopters, while the vertical range is limited to less than three diopters.

The lid can be suspended from the frontalis muscle with fascia lata if the continuity of the levator cannot be restored. An incision is made parallel to and just above the free border of the upper lid and the tarsus is exposed (Fig 582*A* *B*) Fascia lata, approximately 2.5 cm square is divided forming three extensions from the common base which is then attached to the entire length of the tarsus by means of fine sutures (Fig. 582*C*)

The three separated strips are pulled upward through small incisions established laterally centrally and medially above the eyebrow the lid is pulled upward evenly to the desired level by means of these multiple strips notching of the lid margin which is a frequent result when but one strip of fascia is employed is thus avoided The fascial slings are anchored to the frontalis muscle by buried sutures placed at the level of the incisions The ends of the fascia are extended upward beneath the skin by means of mattress sutures brought out through the skin and tied over the gauze (Fig 582*D*). The incisions in the lid and above the eyebrow are closed the mattress sutures are withdrawn at a later date. Figure 583 illustrates complete ptosis of the upper lid and the result following surgical correction (Kazanjian, 1949)

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Two stab incisions are made through the skin of the upper lid, 2 mm above the lid margin and about 2 cm. apart and are placed symmetrically about 7 mm from the medial and lateral canthus, respectively Using a Berbecker (size 8) needle or a fine Reverdin needle a strip of fascia lata is placed as a horizontal mattress suture

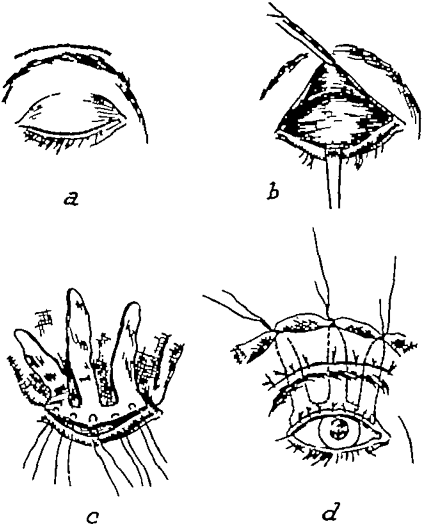


FIG 582. Fascia lata suspension in traumatic ptosis of the eyelid

A. Drawing illustrating incisions for the operation.
B. Exposure of the tarsus.
C. Tongue-shaped piece of fascia lata sutured along its base to the tarsus.
D The fascial strips are pulled upward and held anchored

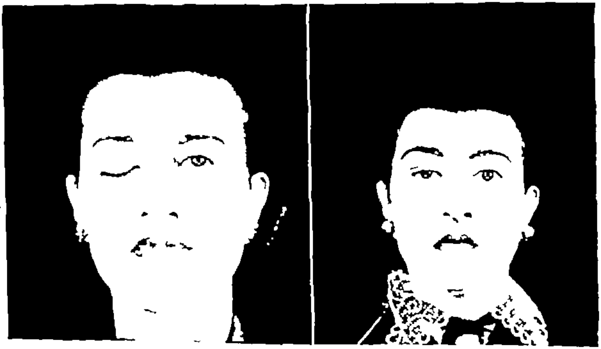
A  B

FIG 583. Traumatic ptosis of the upper lid

A. Photograph showing complete ptosis of the right upper lid resulting from severance of the levator in automobile accident.

B. Photograph after operation for fascia lata suspension, as illustrated in Figure 582.

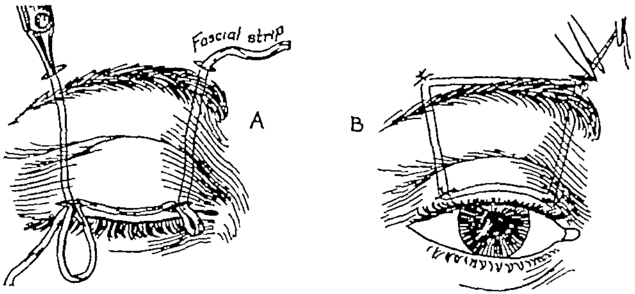


Fig 584 Technique of the Friedenwald-Guyton (1948) and employing fascia lata.

A. *After making two small stab incisions in the skin of the upper lid the fascial strip is threaded through the dermis of the skin of the eyelid.* The fascial strip is threaded up by means of a Reverdin needle to two small stab incisions made immediately above the eyebrow

B. The fascial strip is threaded through the fascial insertion of the frontalis muscle The ends of the suture are tied and the knot buried.

through the previously established skin incisions (Fig 584*A*) The horizontal portion of the suture tract above the lid margin must traverse the dermis of the overlying skin the suture will be torn away if it is *merely passed through the loose tissue be*neath the skin of the eyelid. Two small stab incisions are made at the upper border of the eyebrow one 5 mm lateral to the nasal termination of the brow and the other ap*proximately 3 cm. lateral to the first (Fig* 581*B*) each incision extends to the periosteum The horizontal portion of the suture above the eyebrow should traverse the fascial insertion of the frontalis muscle· the *suture is then tied and the knot buried.*

The purpose of the suture in traumatic ptosis is to obtain scar tissue formation to re-establish the continuity of the severed ends of the muscle· the suture has a sup*portive action during the healing period*

Reconstruction of the Eye Socket

Following enucleation of the eyeball and removal of soft tissues from the eye socket considerable contraction of the conjunctiva *lining* of the eye socket occurs, unless support is introduced into the cavity at an early stage of treatment. The accepted method of reconstruction consists of lining the eye socket with a skin graft using dental *compound or an acrylic mold as a carrier* We have used this method previously but have recently adopted another procedure which employs a graft of oral mucosa and assures a greater percentage of graft survival

*A horizontal incision is extended later*ally about 2 cm from the outer canthus of the eye (Fig 585*A*) thus affording wide exposure of the socket. The adhesions and scars within the socket are excised and the *incision is extended along the border of the* infraorbital ridge (Fig 585*B*) to the periosteum but not through it This is an important step because if the graft does not adhere to the periosteum contracture of the reconstructed socket will occur later This procedure also permits the lower edge of the future prosthesis to rest within the infraorbital ridge An additional measure to insure the adherence of the graft to the periosteum within the orbital rim consists of

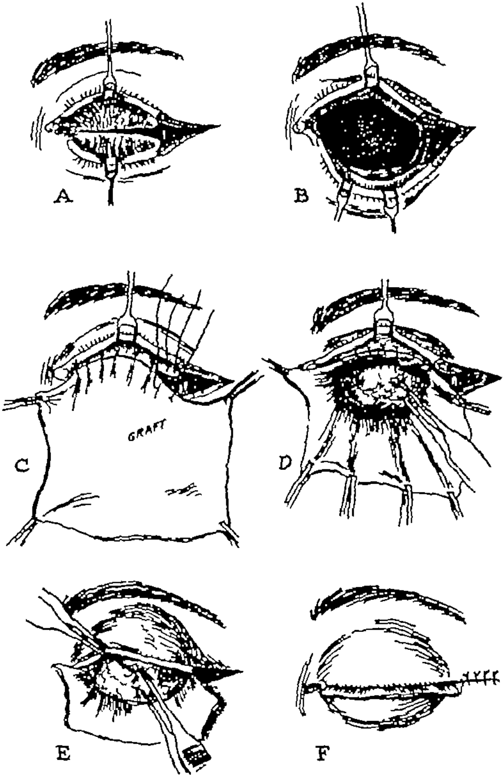


FIG 585 Reconstruction of the eye socket

A Showing incision made in scarred conjunctiva in the socket and through the lateral canthus.
B. The socket has been freed of scar tissue and allowed to expand.
C A mucosal graft is sutured to the margins of the defect.
D and E. Moist cotton pledgets are packed into the socket immobilizing the graft.
F The operation is completed.

A B

Fig 586 Reconstruction of the eye socket

A. Photograph showing left eye socket relined and ready to receive the prosthesis.
B Photograph showing the ophthalmic prosthesis in the socket.

wiring the mold to the rim A small incision is made through the lower eyelid, the rim is exposed and a drill-hole made through it A fine size stainless steel wire passed through the drill hole and the mold provides the anchorage.

The adhesions of the upper eyelid are cut through without injuring the levator muscle. Bleeding is controlled by ligation and by packing the cavity with pledgets of cotton soaked in 1 1000 adrenalin solution. A graft of oral mucosa is removed Full thickness mucous membrane obtained from the inner cheek wall should be thinned by trimming the dermal surface with scissors split thickness mucosa is obtained from the inner aspect of the lower lip with the electric dermatome (see Fig 464 Chapter 18) The graft larger than the raw area of the socket, is sutured to the inner margin of the upper eyelid (Fig 585C D) it is also sutured to the inner and outer canthus, spread loosely into the socket, and packed firmly with cotton moistened with saline solution (Fig 585E) The graft should be placed in firm contact with the raw surfaces of the socket gentle traction on the lower border of the graft assures its even spread.

The incision at the outer canthus is sutured (Fig 585F) cotton padding is placed over the eyelids and a pressure dressing is applied which is left undisturbed for three to four days. The outer bandage is removed at the first dressing if the cotton pads within the socket are dry they are not disturbed, and the outer bandage is replaced.

The socket is examined about a week after the operation and the small cotton pads are moistened and removed. The excess mucosa along the margin of the lower lid is trimmed and the socket is again packed firmly with small pads of moist cotton repacking is repeated at intervals until the socket is completely healed Under no circumstances should the newly created eye socket be left without some form of mechanical support such as cotton packing, or a temporary acrylic or latex prosthesis the permanent prosthesis is inserted after complete healing Figure 586 illustrates a case of reconstruction of the eye socket.

MALUNITED FRACTURES OF THE BONES OF THE ORBIT

Fracture and displacement of the bony orbital walls result in deformity lesions of the lacrimal apparatus interfering with lacrimal function extraocular muscle imbalance downward displacement of the globe and diplopia Such fractures have been associated with fractures of the base of the skull.

Deformities of the Orbital Roof

Deformities of the roof of the orbit usually affect the prominent supraorbital rim following fractures which involve the frontal bone and the frontal sinus (see Chapter

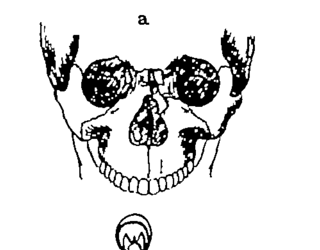


FIG 587 Diagram showing deformity of the medial wall of the orbit.

A. Illustrating deformity resulting from fracture of the left nasal bone and frontal process of the maxilla. Bone fragments fill the medial portion of the orbital cavity

B. The left medial canthus is displaced laterally (From J M. Converse, Arch. Ophth., 31 323 1944)

FIG 588. Deformity of left median canthal area following comminuted fracture of nasal bones and frontal process of maxilla (Case History No. 1)

A. Shows the typical deformity of the left medial canthus which is displaced forward laterally and downward.

B. Result obtained after canthoplasty and dacryocystorhinostomy

(From J M Converse, and B. Smith, Am J Ophth., 35 1103, 1952)

10) Reconstruction of the area by bone grafts is described in Chapter 20

Deformities of the Medial Wall of the Orbit

Malunited fracture of the medial wall of the orbit results from backward displacement of comminuted fragments of the nasal bones and frontal process of the maxilla. These fragments may enter the orbital cavity thus injuring the lacrimal sac (see Fig 250 Chapter 8) or they may be forced into the ethmoidal labyrinth producing a fracture of the orbital wall and resulting in a lessened lateral dimension of the orbit. (See early treatment of such fractures in Chapter 8).

Deformity affects the fractured nasal framework and the region of the medial canthus (Fig 587*A*) The medial canthal ligament is severed or displaced from its bony insertions, resulting in lateral displacement of the ligament. Laxity of the canthal ligament causes the medial canthus to be pulled laterally due to a release of tension upon orbicularis oculi muscle fibers the canthus loses its angular shape, becomes rounded and the caruncle, semilunar fold and a portion of the sclera may be covered by the laterally displaced tissues of the upper and lower lids (Figs 588 589)

The extent of lateral displacement of the deformed canthus can be evaluated by measuring the distance between the mid sagittal plane of the face and the unaffected canthus and comparing it with a similar

FIG 589

A. Appearance before replacement of the left medial canthus by technique shown in Figure 599
B. Appearance after replacement of the medial canthus and reconstruction of the nose.
(From J M Converse Arch. Ophth. 31 323 1944)

measurement on the side of the deformity (Fig 587*B*)

In the normal eyelid the medial palpebral ligament maintains the tautness of the lids against the convex surface of the eye ball Relaxation of the lid margins due to detachment or severance of the medial canthal ligament causes the lacrimal puncta to lose intimate contact with the eyeball the mechanism of collection and evacuation of tears is thus impaired and epiphora results.

More serious however from a functional standpoint is the disturbance of the nasolacrimal apparatus due to direct injury of the sac or obstruction of the nasolacrimal duct from direct laceration by displaced pieces of bone. Repeated episodes of acute suppurative dacryocystitis tend to follow A mucocele may form as a result of chronic obstruction and inflammation and typical viscous fluid is expressed by pressure over the swollen sac which forms a visible and palpable mass in the medial canthal region.

More frequently particularly when the sac itself has been injured the entire medial canthal region exhibits thickened, edematous tender tissues periodic acute inflammatory episodes complicate this chronic dacryocystitis, a purulent exudate being discharged by the lacrimal puncta into the palpebral fissure and conjunctival sac.

It is obvious that the treatment of deformities of the medial wall of the orbit often requires surgery of the lacrimal sac.

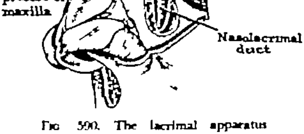


FIG 590. The lacrimal apparatus

Surgery of the Lacrimal Apparatus

ANATOMICAL CONSIDERATIONS. The lacrimal draining mechanism is formed by the puncta canaliculi lacrimal sac and lacrimal duct. The sac is lodged in the groove formed by the frontal process of the maxilla and the lacrimal bone situated in the anterior portion of the medial wall of the orbit (Fig 590). Tears collected from the medial extremity of the palpebral fissure by the puncta are conducted to the sac by the canaliculi the tears are evacuated from the sac into the nose through the nasolacrimal duct

The lacrimal puncta are openings of the canaliculi within the palpebral fissure. The puncta are round oval or slit like, are approximately 0.25 mm. in diameter and are located at the apex of the lacrimal papillae approximately 6 or 7 mm lateral to the medial canthus. The papillae are in contact with the eyeball and lacrimal sac in the normally functioning eyelid. The papilla and punctum no longer contact the globe when the lid sags, due to paralysis or cicatricial ectropion. The re-establishment of contact of the punctum with the globe is a necessary measure in such conditions to re-establish lacrimal function.

The punctum opens into the canaliculus which is horizontally directed for a distance of 7 to 10 mm. The canaliculi join at right angles with vertically directed funnel-shaped canals, which are from 2 to 2.5 mm long. The canaliculi usually join each other before reaching the sac and empty into the lacrimal sac near its upper portion.

The lacrimal sac is approximately 12 mm. long and 5 mm. wide and may be greatly increased in size in conditions such as mucocele. The thickness of the walls of the sac varies from 0.5 to 0.7 mm. The lower end of the sac fuses with the nasolacrimal duct which is tunneled through the frontal process of the maxilla.

The bony portion of the nasolacrimal duct is approximately 10 mm. long; the entire length, with the covering soft parts is from 15 to 20 mm. The diameter of the nasolacrimal duct varies between 3 and 7 mm; its direction is downward backward and inward and it opens in the inferior nasal meatus beneath the inferior turbinate. Exploration of the lacrimal ducts is accomplished with the aid of conic dilators, probes and a lacrimal syringe.

THE THREE-SNIP OPERATION FOR STENOSIS OF THE PUNCTUM Stenosis of the punctum may result from lacerations of the lid. An operation described by Graves (1926) modified by Thomas (1951) and by McLaughlin (1950) is performed in the following manner The lower canaliculus is dilated to allow the entrance of one blade of a fine pair of sharp straight scissors (Fig 591*A*) A first slit 2 mm long, is made parallel to the margin of the lid along the edge of the palpebral conjunctiva away from the free margin of the lid Two additional snips are made at each extremity of the initial horizontal incisions these extend downward through the palpebral conjunctiva and are joined at an angle. The triangular piece of tissue thus delimited by the three incisions is excised (Fig 591*B*) Slitting the entire canaliculus is an obsolete operation is mechanically unsound and is seldom indicated

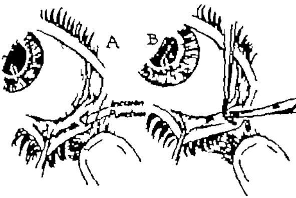


Fig 591 The three snip operation
A. Outline of triangle to be excised.
B. Triangle is being excised.

SLITTING THE PUNCTUM This procedure consists in making one slit the first of the three described above, and may suffice in cicatricial stenosis of the punctum

MEDIAL CANTHOPLASTY A technique for improving lacrimal drainage and tightening the lower lid in facial paralysis and similar conditions is exemplified in Figure 592 (Cole 1957) An initial incision is made through the skin from a point 1 mm. lateral and anterior to the lower punctum, parallel medially with the lower margin of the medial canthus. The incision is then extended upward and medially approximately 10 mm. nasal to the medial canthal angle. Another incision extends along the margin of the upper lid and joins the first incision forming a V-shaped incision An oblique incision is then extended from the apex of the

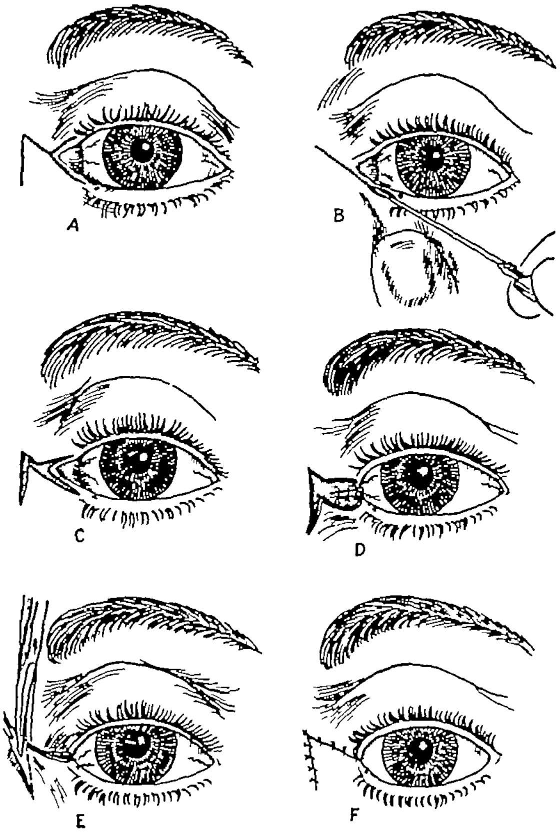


FIG 592. Medial canthoplasty

A. Outline of incisions
B. *Probe placed in the canaliculus in order to avoid severing this structure*
C. After completion of incisions.
D. *The edges of the medial canthus are sutured by means of inverting sutures.*
E. Traction is placed upon the skin flap and excess skin removed
F. *The skin incision is sutured.*

FIG 593 Medial canthoplasty to improve lacrimal drainage in facial paralysis.

A and C. Left facial paralysis showing the typical sagging of the lower lid, eversion of the lower punctum and exposure of the caruncle.

B and D Result obtained by medial canthoplasty illustrated in Figure 592

V toward the nose terminating at the junction of the thin eyelid skin with the thicker nasal skin (Fig 592*A B C*) The flap outlined by the incision is undermined Traction on the skin flap tightens the lower lid. The margins of the medial canthus are sutured to each other with interrupted inverting 6-0 chromic catgut sutures (Fig 592*D*) Traction is exerted on the skin flap the excess skin is excised (Fig 592*E*) and the skin edges are sutured (Fig 592*F*) This gratifying procedure results in surprisingly little blemish and serves to tighten the lower lid and approximate the puncta against the eyeball thus improving the lacrimal drainage (Fig 593)

OPERATION TO TIGHTEN THE SAGGING LOWER EYELID Instead of splitting the lid margin the incision is extended from a point 10 mm. lateral and 2 mm below the lateral canthus medially for a distance of approximately 25 mm. the incision thus lies about 2 mm below the line of the eyelash (Fig 591*A*) A vertical incision 10 mm. in length is extended downward through the skin from the beginning of the first incision The triangular flap thus formed is undermined inferiorly and beyond the termination of the initial incision A triangular section of the lid is then excised the width of the base of the triangle is determined by the amount required to shorten the horizontal measurement of the lid (Fig 594*B*)

A figure-of-eight suture through the upper lid (Minsky 1942) is employed to close the defect formed by the removal of the lower lid section (Fig 594*C*) The suture is in the plane of the pretarsal fascia and at the level of the gray line as it crosses the interpalpebral fissure a dermalon suture is excellent for this step of the procedure. Auxiliary 6-0 chromic catgut buried sutures are used to close the tarsal defect and at the lid margins. The excess at the temporal extremity of the skin flap is excised (Fig 594*D*) and the skin wound is closed with interrupted 6-0 silk sutures (Fig 594*E*) The skin sutures are removed at the end of five days and are replaced with a collodion strip for

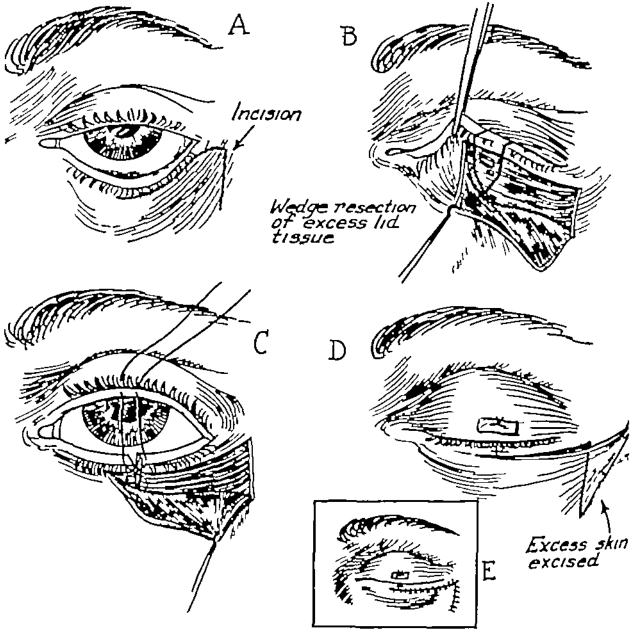


FIG. 594. Operation to tighten the sagging lower eyelid.

A. Outline of incision placed 2 mm. below the eyelash line.

B. After separating the eyelid skin from the orbicularis oculi fibers a full thickness wedge of lower lid tissue is outlined.

C. Closure of the area of the wedge excision by means of a figure-of-eight suture which also serves to approximate the eyelids.

D. Excision of excess skin.

E. Appearance at completion of the operation.

a few days. The figure-of-eight suture is not removed until the seventh postoperative day. Little or no deformity results if the technique is performed in a meticulous fashion. Additional techniques combining both medial and lateral canthoplasties are discussed in Chapter 27 (see Figs. 1070, 1071).

REPAIR OF LACERATED CANALICULUS. Repair of the severed canaliculus is an early requirement after the laceration of the lid or it may be done in a later procedure following healing of the wound in the course of a secondary repair of the lid. Early repair is always a more satisfactory procedure whenever possible.

Section of the canaliculus should be suspected in all wounds which involve the medial third of the lid. Lacerations of the medial third of the lid usually cross the lid margin about 2 mm. medial to the punctum and extend through the entire lid substance, detaching the medial canthal ligament from the tarsus.

A suture is placed through both fragments of the lid about 1 mm below the severed canaliculus. A second suture is passed through both fragments of the lid above the severed canaliculus. The laceration falls into good alignment when these key sutures are tightened a probe may then be passed through the punctum across the laceration and into the proximal fragment of the severed canaliculus. If difficulty is encountered in locating the proximal portion of the canaliculus, retrograde probing from the opposing punctum can be accomplished with a U-shaped silver probe. Another means of localization is puddling saline in the lacrimal lake and bubbling air in a retrograde direction from a lacrimal needle in the upper canaliculus. Sterile milk may also be injected as a tracer solution

After the rent in the canaliculus is localized the wound is closed with a section of No 2 silver probe in place or over a small polyethylene tube (Fig 595) A double-armed suture is passed through the tarsal edge across the wound into the stump of the medial canthal ligament, engaging the periosteum at the anterior lacrimal crest and out through the skin lateral to the bridge of the nose. The conjunctiva is closed with fine chromic catgut sutures. The skin is then closed and the double armed suture on the lateral aspect of the nasal bridge is tightened and tied over a small rubber plate. The tip of the polyethylene tube is then fixed to the skin of the lower lid to prevent the tube from entering the interpalpebral fissure and causing corneal irritation The lids are sutured near the mid point and a moderate pressure head dressing is applied. The dressing and skin sutures are removed after six

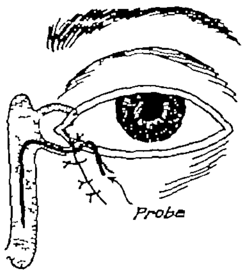


FIG 595 Repair of lacerated canaliculus The drawing shows a fine caliber silver probe threaded through the punctum to the canaliculus and lacrimal sac to insure the continuity of the canaliculus. The external wound has been sutured.

days the probe and tube remain undisturbed The medial canthal ligament suture may be removed after eight days. The probe and tube should be maintained in position for three weeks. One should observe the punctum to insure against erosion by the probe or tube. Erosion is due to defective contour of the probe or tube one must be aware of this danger at the time of surgery to prevent this complication

DACRYOCYSTITIS. A multiplicity of causes may result in interference with lacrimal function the puncta are not applied against the ocular globe because of entropion or ectropion cicatricial stricture of a canaliculus is due to a healed laceration of the lid the sac is injured either by direct penetration of a foreign body or a comminuted fragment of bone, or the nasolacrimal duct may be obstructed. The sac becomes dilated when clogged and part of its contents flows back through the lacrimal puncta into the palpebral fissure. Fluid injected into the canaliculus should normally pass through the lacrimal system and appear when the patient blows his nose. If on pressure of the sac, the fluid flows back and is clear and thin there may be obstruction without infection. If the sac is very dilated it is a sign

that the lacrimal flow has been interrupted for a long time, a condition designated as a *mucocele*.

The enlarged sac or mucocele forms a visible and palpable mass in the medial canthal region below the inner angle. A mucopurulent secretion from the inflamed mucosa and frequently the viscous fluid characteristic of mucocele may be expressed by pressure over the swollen sac.

Distention of the lacrimal sac may cause kinking of the common canaliculus; when this occurs, the fluid becomes trapped in the lacrimal sac; distention results in pain. Since it is not possible to aspirate the sac contents through the kinked common canaliculus, direct aspiration through the skin with a No. 20 gauge needle may be required to relieve the acute distention and also to release the mechanically kinked and secondarily obstructed canaliculus. Instruments can usually be introduced following such aspiration through the canaliculus.

Attacks of acute dacryocystitis with redness, swelling and pain may occur with swelling of the entire orbital region and closure of the eyelids over the globe. Hot applications and antibiotics are indicated; incision and drainage are essential when the purulent collection has become fluctuant. A suppurating lacrimal sac is a source of constant danger because even a slight abrasion of the cornea may become infected and ulcerated.

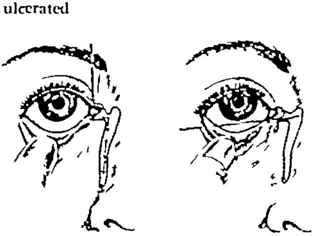


Fig. 590. Probing the canaliculus. Successive positions assumed by the probe, first vertically (*left*), then horizontally (*right*).

Treatment of dacryocystitis. When dilatation of the lacrimal punctum is required, a topical anesthetic solution is injected into the canaliculus and a thin probe is introduced. The probe is directed vertically and is rotated 90 degrees and then advanced medially while the canaliculus is stretched (Fig. 590). The probing must be done carefully in the manner described to prevent the probe from striking a fold of mucosa and perforating the canaliculus. The probe is pressed forward until it reaches the sac. Penetration into the sac is evidenced by contact of the tip of the probe with the bony wall of the orbit; the handle is elevated vertically and inclined slightly forward, directly into the duct. After the lacrimal sac has been reached, it is advisable to withdraw the probe and inject saline or an anesthetic solution through the canaliculus; if the fluid passes into the nose, further probing should be discontinued, for the free passage of the solution indicates elimination of the obstacle in the nasolacrimal duct. The modern concept of dacryocystorhinostomy treatment is surgical, replacing the former method of periodic probing to relieve obstruction.

Simple surgical procedures can be used to correct the eversion of the eyelid margin and punctum. Extirpation of a small piece of conjunctiva is often sufficient to adequately correct the ectropion of the lid margin responsible for pulling the punctum away from the ocular globe.

In permanent stenosis of the punctum, removal of the posterior wall of the punctum may be accomplished with small scissors (see Fig. 591).

Extirpation of the sac may be necessary in rare cases of its destruction by multiple lacerations and scarring or by prolonged suppuration and necrosis.

Toti (1901) introduced dacryocystorhinostomy, causing the tears to enter the nose by perforating the lacrimal fossa. Mosher (1915, 1923) improved upon this procedure by a technique in which the anterior margin of the opening in the sac was approximated

catgut sutures to the anterior margin bone opening Further modifications s operation by Dupuy Dutemps and guet (1921) with a much higher per ge of success, consisted in careful su g of the nasal mucosa to the mucosa of crimal sac.

cryocystorhinostomy is required when asolacrimal duct is obstructed. This tion may also be necessary in more licated situations when bone fragments orced into the orbit or the medial pal l ligament is severed. Figure 599 les the technique of the dacryocysto-stomy operation and also the tech s employed by the authors to restore nedial wall of the orbit and reattach iedial canthal ligament in one stage.

CRYOCYSTORHINOSTOMY COMBINED WITH NSTRUCTION OF THE MEDIAL ORBITAL , AND REATTACHMENT OF THE MEDIAL EBRAL LIGAMENT Traumatic lesions of acrimal apparatus are often accompa by malunited fracture of the bone and hment of the medial palpebral liga these conditions should be treated omitantly The extent of the local ige can be evaluated from the history e accident the type of injury sustained the displacement of bony and soft tis of the area The nasal pyramid is lly deformed (see Figs. 588 and 589) ous irregularities may be observed in nasal cavity such as deviation of the im adhesions between the middle or ior turbinate and septum enlargement ie middle turbinate and suppuration ie middle meatus as a result of maxil ethmoidal or frontal sinusitis.

one of our cases, synechiae had ob-ated the space between the septum and entire lateral nasal wall on the affected In another case (Fig 597) a fragment n exploded shell was lodged in the an or portion of the ethmoidal labyrinth could not be removed until after the rior tip of the middle turbinate was cted and an anterior ethmoidectomy was

FIG. 597 Photograph of Greek Army officer wounded by fragment of land mine (Case History No. 2)

A. Note the widening of the left canthal area by penetration of multiple fragments of displaced bone. The soft tissues are thickened due to chronic dac ryocystitis.

B. After removal of bone fragments from the left median canthal area and of fragment of land mine, re-attachment of the medial palpebral ligament and dacryocystorhinostomy The right orbital cavity was obliterated.

(Figs. 597 to 601 from J M. Converse and B. Smith, Am. J Ophth. 35 1103, 1952)

done (see Case History No 2) Successful dacryocystorhinostomy depends upon re-establishment of nasal function.

Clinical examination should be supple mented by stereoscopic radiographic investi gation Displaced fragments of bone in the nasal lacrimal and ethmoidal areas may be demonstrated by roentgenograms x-ray ex amination after lipoidal injection of the lacrimal apparatus reveals the contour of the lacrimal passages or of their remnants (Fig 598) In the Waters position lipoidal may be identified in the eyelash lines, thus demonstrating the relationships of the pal pebral fissure lacrimal sac and orbital wall (Fig 598*B*).

Anatomically the lacrimal sac is intri cately related to the medial palpebral liga ment the ligament splits into two portions lateral to the sac, enveloping the sac and blending with its walls (see Fig 523) The anterior portion of the ligament is inserted into the anterior lacrimal crest the pos-terior division terminates along the pos-terior crest of the lacrimal groove. The an

FIG 598

A. Roentgenogram of patient shown in Figure 597*A* taken after lipiodol injection of the lacrimal system. Shows remnant of left lacrimal sac displaced downward and laterally

B. Roentgenogram of another case after lipiodol injection, in the Waters position, showing a normal left lacrimal apparatus. The contrast medium extends to the inferior meatus of the nasal cavity It also demonstrates a dilated, obstructed right lacrimal sac. Note also the canaliculi and the lash lines stained by the contrast medium.

terior segment of the ligament is stronger than the posterior but the pull tensing the eyelids and applying them against the eye ball is exerted through the posterior portion of the ligament by contraction of Horner's muscle: this small muscle, located immediately behind the ligament is attached to the bone behind the posterior lacrimal crest (Fig 599*A* *B*) these anatomic considerations are of surgical significance

The reattachment of the ligament and restoration of the lacrimal apparatus should be completed in one operation The ligament should also be reattached to the posterior lacrimal crest to obtain the posteriorly directed pull supplied by Horner's muscle The rationale for performing the single-stage operation is to avoid the inconveniences of a later operation in a scarred area

Methylene blue solution is injected through the lower punctum into the sac the stained sac can thus be identified in the course of the operation

Operation A curved incision made over the frontal process of the maxilla sufficiently high to avoid the skin of the eyelid extends through the skin subcutaneous tissue and periosteum The incision is placed anteriorly over the frontal process of the maxilla to avoid the webbing scar which follows an incision closer to the canthal area

The periosteum is raised from the bone with a small elevator along the medial orbital wall over the lacrimal groove and lamina papyracea (Fig 599*C* *D*) Malunited bone fragments which protrude into the orbital cavity are resected (Fig 599*E*). The lacrimal sac or its remnant is elevated and the medial wall of the orbit is exposed by lateral retraction of the orbital contents (Fig 599*F*)

The orbital wall when greatly thickened by overlapping bony fragments, is thinned with a large electrically driven bur to permit adequate replacement of the canthus. The remains of the palpebral ligament are identified anteriorly to the canaliculus by inserting a small probe through the punctum into the lower canaliculus (Fig 599*F*).

A circular section of bone about 10 mm. in diameter is removed from an area below and anteriorly to the site of the lacrimal

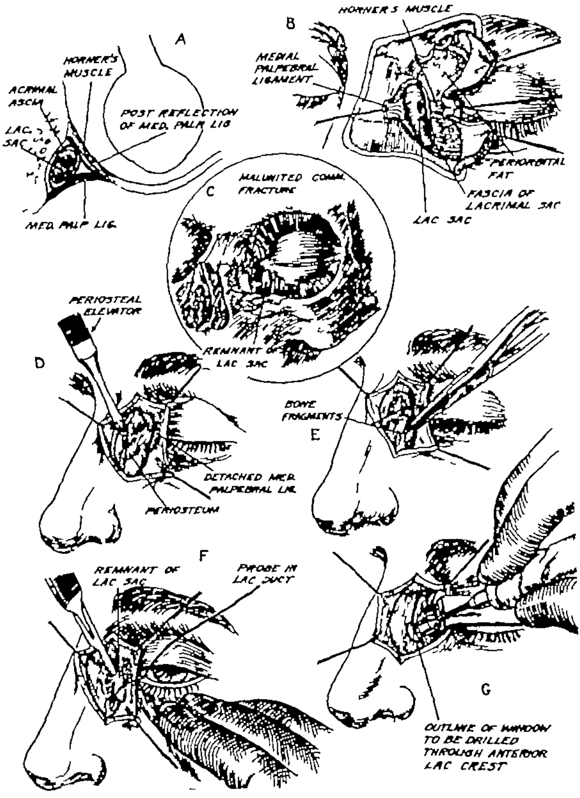


FIG 599 Technique of combined medial canthoplasty and dacryocystorhinostomy

A. Diagram showing the splitting of the medial palpebral ligament into anterior and posterior portions surrounding the lacrimal sac. Note the position of Horner's muscle.

B. Diagram showing the relationship of Horner's muscle with the posterior slip of the medial palpebral ligament.

C Diagrammatic representation of comminuted bone fragments in the medial portion of the left orbit.

D Showing the beginning of the subperiosteal elevation of the medial wall of the orbit.

E. Resection of protruding overlapping pieces of bone with the rongeur

F Showing placing of probe in the lower canaliculus to help locate the anterior palpebral ligament and define the limits of the sac.

G Outline of window to be drilled through anterior lacrimal crest.

(Continued in next figure)

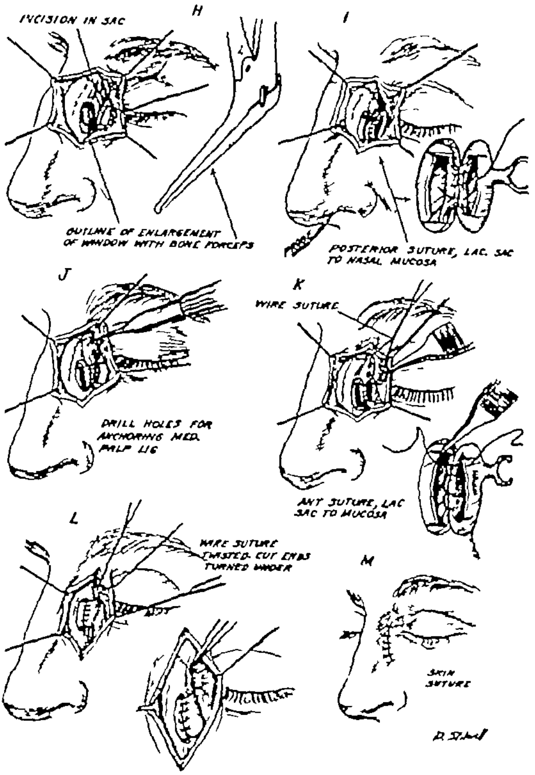


FIG 599 (Continued)

H Showing the I-shaped incision practiced in the sac wall and outline of the bone to be resected to enlarge the window

I The nasal mucosa has been incised and the posterior flap of the nasal mucosa is sutured to the posterior flap of the sac.

J Holes being drilled in the medial orbital wall for the anchorage of the medial palpebral ligament with wire

K. Placing of stainless steel wire for the anchorage of the medial palpebral ligament.

L. The stainless steel wire is twisted and cut. The dacryocystotomy procedure is completed

M. Suture of the skin wound completed.

groove, by an osteotome or preferably by means of a motordriven trephine (Fig 599G) This opening is made without cutting through the nasal mucosa the trephine osteotomy is enlarged by rongeurs to a diameter of 15 to 20 mm. (Fig 599H)

Placing a blunt-tipped probe through the lower punctum into the sac, a vertical I shaped incision is then made through the nasal mucosa (Fig 599I) The anterior tip of the middle turbinate, if hypertrophic, should be resected to prevent clogging the passageway to the nasal fossa

The site of reinsertion of the palpebral

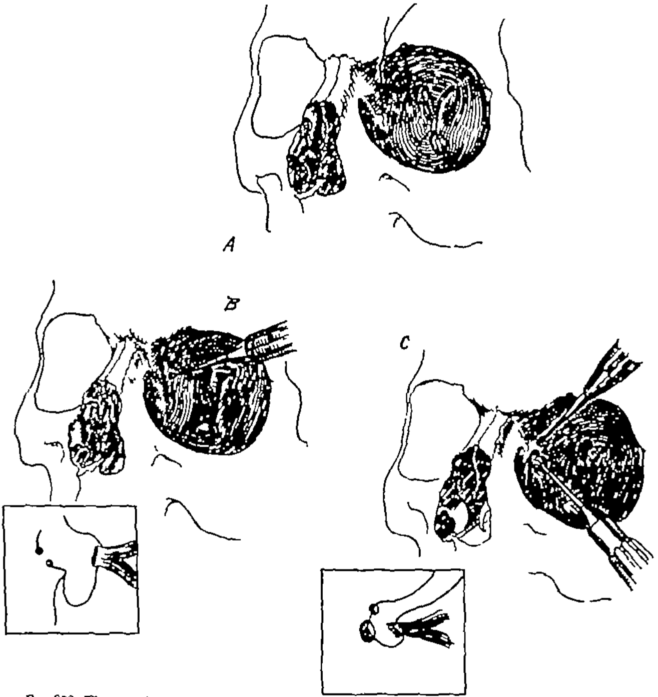


FIG 600. Three methods for placing drill holes in the medial orbital wall for anchorage of the medial palpebral ligament.

A. The holes are placed one above the other

B. The holes are placed one behind the other

C. One large hole is made at the site of implantation of the medial palpebral ligament. With a smaller drill a second channel is established, joining the larger hole at a diagonal. The stump of the palpebral ligament is drawn up into the larger bony opening

FIG 601 Deformity of right medial canthus caused by laceration of the soft tissues and comminuted fracture.

A. Preoperative view showing displacement of the right medial canthus and traumatic ptosis of the upper lid. The right eye had been enucleated

B. Postoperative photograph showing replacement of the right medial canthus, corrected ptosis, artificial eye

ligament is then selected it should be at the posterior crest of the lacrimal groove or slightly posterior to it The position of the medial canthus of the unaffected eye serves as a guide when normal landmarks are absent

Two holes are made with an electrically driven round bur (No. 6) penetrating through the bone but sparing the mucosal lining of the nose (Fig 599J) A small curved needle is used to threat fine stainless steel wire through one opening and out of the other (Figs 599J and 600A B)

A variation of this technique is to drill a large hole in the bony wall followed by another smaller perforation which joins the larger opening at a diagonal (Fig 600C). It is thus easier to thread the wire and the stump of the palpebral ligament can be drawn up into the larger hole The wire is looped either into the medial palpebral ligament or the stump of the ligament and is then held in readiness while proceeding with surgery of the lacrimal apparatus (Fig 599K)

Having established the bony opening into the nose and prepared the holes for fixation of the palpebral ligament fine chromic sutures are placed to approximate the edge of the posterior flap of the sac with the edge of the posterior nasal mucosa flap similar sutures which remain untied are placed through the edges of the anterior flaps (Fig 599K L)

As the wire is tightened (Fig 599L) resistance in the area of the floor of the orbit in its medial portion may prevent correct repositioning of the canthus, for the scar tissue pulls the angle of the eye downward shortening the septum orbitale. One should dissect downward underneath the orbicularis oculi and incise the periosteum along the rim of the orbital floor to free the attachment of the septum orbitale. If difficulty is experienced in correctly replacing the medial canthus the lateral canthal ligament is exposed through a small skin incision at the outer orbital margin and then severed One may also cut the tarso-orbital fascia at the outer orbital margin.

After correct replacement the canthus should resume its angulated shape and the caruncle be fully exposed (Figs. 588, 590 597 and 601)

The stainless steel wire attaching the palpebral ligament to the orbital wall, is then twisted upon itself and cut (Fig 599L). The fine chromic sutures which approximate the posterior flap of the sac to the posterior nasal mucosal flap are tied and similar sutures are placed through the edges of the anterior flaps and tightened The operation is completed by careful approximation of the edges of the skin incision (Fig 599M) An interpalpebral mattress suture occludes the eyelids and a pressure dressing is maintained for five days.

If the remains of the palpebral ligament cannot be identified or if the canthus itself has been destroyed the wire sutures are placed through the medial end of each tarsus (Callahan 1950)

When a portion of the sac has been destroyed and an insufficient amount of it is left to permit this type of operation (Case History No 2) the remnants of the sac supported on a probe passed through the

lower canaliculus, are brought through a nasal window and held by sutures passed into the nasal cavity out through the external nares and are then anchored to the cheek by adhesive tape.

RESTORATION OF THE NASOLACRIMAL SYSTEM WHEN THE CANALICULI AND A PORTION OF THE SAC HAVE BEEN DESTROYED. The stump of the lacrimal sac should be joined with the palpebral fissure in order to provide evacuation of the tears. The procedure is similar to that described by Stallard (1940) and the exposure to that employed for an external dacryocystorhinostomy The upper portion of the nasolacrimal duct is located if the sac is completely destroyed. A 4-0 silk suture is placed through the remains of the sac and brought out into the lacrimal lake by perforating the tissue lateral to the remains of the sac. This suture indicates the position of the new conjunctival canal which must join the nasolacrimal duct with the palpebral fissure

Another technique effective when the sac is destroyed, consists in placing an 18-gauge polyethylene probe into the nasolacrimal duct and extending the probe into the nasal cavity through an opening in the lateral wall of the nose. The other end of the probe is threaded through the tissues into the conjunctival sac and the ends of the probe are tied together The patient is instructed to move the probe periodically until a new channel is established between the conjunctival sac and the nasal cavity

CASE HISTORIES. *Case I* M K. a woman aged 19 suffered multiple lacerations of the face and compound comminuted fracture of the nasal bones in an automobile accident. Emergency treatment was rendered at a nearby hospital where the facial wounds were sutured and the nasal fracture reduced.

The patient was examined 4 months after the accident. She showed a number of deformities about the face numerous facial scars, notably a vertical contractile scar extending from the left eyebrow downward across the root of the nose and flatness of the nasal bridge but the most obvious deformity was the displacement of the left medial canthus covering the caruncle (Fig 588*A*)

The patient complained of epiphora and of intermittent attacks of pain, redness and a purulent discharge from the medial aspect of the conjunctival sac.

Palpation revealed the presence of bone which filled the medial canthal region Roentgenographic examination showed multiple fractures of the nasal bones, the frontal process of maxilla and the medial portion of the orbital floor Bony fragments of the nasal bone and frontal process appeared to have been pushed backward over the lacrimal bone and lamina papyracea

Disruption of the left nasolacrimal system was confirmed when saline solution introduced by a syringe into a punctum and canaliculus failed to reach the nasal cavity roentgenographic examination after lipiodol injection confirmed the obstruction

A vertical incision was made over the frontal process of the maxilla and the bony wall was exposed by subperiosteal elevation The sac was visualized after injecting methylene blue solution through the lower canaliculus

The protruding bone from the medial wall of the orbit was removed with a large electrically driven bur until normal contour was achieved The remains of the medial palpebral ligament were identified and two small holes were drilled in the medial wall of the orbit to anchor the ligament.

A dacryocystorhinostomy procedure was then done and the medial ligament was anchored to the orbital wall with stainless steel wire. The wire was twisted and cut and the remaining ends of wire twisted toward the bone. The wound was closed with fine sutures.

A pressure dressing was applied after placing temporary lid sutures. The dressing was so uncomfortable at the end of the first

postoperative day that it was removed and the cornea was inspected.

Although lid sutures were placed, a corneal abrasion had been responsible for the discomfort. Whether the abrasion was due to surgical trauma or a displaced cilium was difficult to determine. The pressure dressing was dispensed with and the corneal abrasion received primary consideration The abrasion healed in 24 hours.

The skin sutures were removed on the fifth postoperative day The lacrimal duct was patent. Normal contour of the medial canthal region was re-established and good drainage through the nasolacrimal apparatus was restored although the patient still complained of slight epiphora when subjected to strong light (Fig 588*B*)

Case 2 V T., a Greek war veteran aged 24 years, was injured in combat by an antipersonnel mine (Fig 597*A*) The injury to the nose and both eyes resulted in loss of the right eye widening of the intercanthal distance left dacryostenosis and pansinusitis. The injured right globe had been enucleated.

He was examined one year after the injury The left orbital region exhibited typical lateral displacement of the medial canthus with covering of the caruncle and relaxation of the lids.

Marked widening of the distance between the mid-sagittal plane of the face and the medial canthus was noted. Palpation revealed displaced bony fragments filling the medial canthal area The patient had epiphora and a history of repeated swelling in the left medial canthal area the tissue was brawny and tender to palpation

Intranasal examination showed adhesions between the septum and the left middle turbinate obstructing the nasal airway and also an abundant purulent discharge

Roentgenographic examination showed a piece of steel about 2 by 3 cm in the left ethmoidal labyrinth A submucous resection of the septum left ethmoidectomy removal of the foreign body and left radical antrum operation were done

After reaction from the sinus surgery subsided a lipoidal study showed the source of the left lacrimal infection to be focused in a narrow remnant of the left lacrimal sac situated near the nasal aspect of the lower left orbital margin The left medial canthus was displaced toward the temple about 8 mm The bone fragments nasal to the canthus were irregular and prominent.

The left medial orbital wall was exposed through a vertical incision 5 mm. nasal to the left medial canthus under intratracheal anesthesia An aqueous solution of methylene blue was injected into the lower canaliculus to stain the remaining lacrimal passage for purposes of identification during dissection

After freeing the adhesions, the thickened, prominent bone was reduced with rongeurs and a motor-driven bur The lacrimal sac was identified as a narrow tube communicating with the upper and lower canaliculus of sufficient length to consider connecting it with the nasal cavity

An osseous window 10 mm in diameter was established with an electrically driven trephine The nasal mucous membrane was incised and sutures attached to the lacrimal remnant were passed through the wound and brought out through the left nostril

Two holes were drilled in the bone above and behind the trephine osteotomy to wire the medial canthal ligament to the bone After the wire was twisted and cut, the sutures protruding from the left nostril were fixed to the skin surface of the left cheek with adhesive The skin wound was closed with fine sutures. The lids were closed with a temporary suture and a pressure dressing was aplied.

The dressing was removed on the fourth postoperative day and the temporary lid suture was removed Irrigation through the lower canaliculus entered the nose The skin sutures were removed on the fifth postoperative day The sutures attached

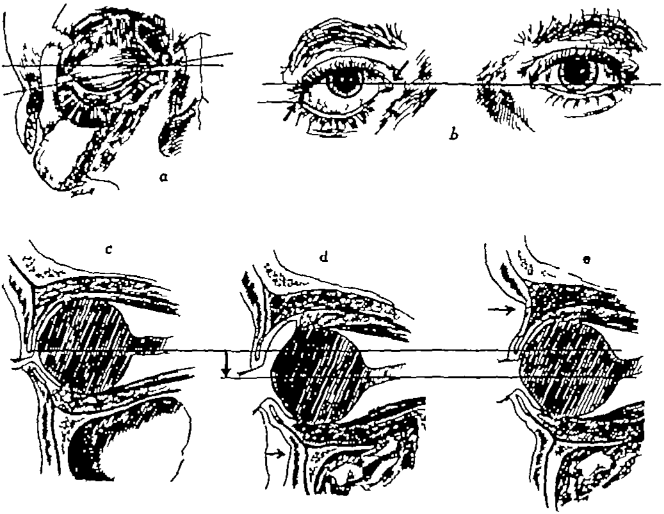


FIG 602

A. Downward displacement of the lateral canthus in cases of frontozygomatic separation

B. Degree of downward displacement of the right lateral canthus as measured by the ruler test.

C. Normal anatomic relationship of the orbit to the orbital contents.

D Downward displacement of the orbital contents, caused by depression of the floor of the orbit. The lower lid is retracted because the septum orbitale is pulled backward by scar tissue.

E. Deepening of the superior palpebral sulcus due to ptosis of the globe.

(From J M. Converse and B. Smith, Arch. Ophth. 44 1 1950)

to the lacrimal sac were removed on the eighth day The postoperative course was uneventful

The position of the canthus was restored and the lacrimal system has remained free from obstruction and infection (Fig 597*B*) The patient was last observed eighteen months following surgery the cosmetic and functional results had remained satisfactory

Deformities of the Lateral Wall of the Orbit

In malunited fracture of the zygomatic bone with downward displacement, the zygoma may be detached from the frontal bone and a gap is noted in the lateral wall of the orbit. The lateral canthus and the attachment of the lateral palpebral ligament to the zygoma are displaced downward (Fig 602*A* *C*) Since the lateral portion of the floor of the orbit is formed by the zygoma a deformity occurs in that region In recently consolidated malunited fractures the continuity of the lateral wall of the orbit is re-established by replacing the malunited zygoma following osteotomy Two small horizontal incisions are made, one lateral to the outer canthus along the orbital rim to expose the frontozygomatic area and the other in the lower eyelid to

expose the zygomaticomaxillary junction (see Fig 283 Chapter 9) Areas of malunion are cut through with a small osteotome The zygoma is then raised the temporal approach is preferred for this procedure because strong leverage is usually required Interosseous wiring then provides fixation

As previously stated in Chapter 9 prudence should be exerted in attempting secondary osteotomy of the malunited zygoma In old malunited fractures, secondary osteotomy is not without danger including that of provoking blindness by a fracture line radiating to the optic canal. A more prudent technique is to elevate the level of the floor of the orbit by a bone graft detach the lateral palpebral ligament and reattach it at a higher level on the lateral orbital wall

Deformities of the Orbital Floor

In Chapter 9 we discussed the consequences of fracture of the floor of the orbit. As a result of frontozygomatic separation fracture of the thick lower orbital rim comminution of the thin portion of the orbital floor escape of orbital fat into the maxillary sinus, or gross downward displacement of the orbital contents into the maxillary sinus, two serious complications occur—diplopia and enophthalmos The early treatment and prevention of these complications are discussed in Chapter 9

Diplopia Due to Fracture of the Orbital Floor

Diplopia following fractures of the floor of the orbit results from one of two conditions (1) loss of the supportive function of the orbital floor and ptosis of the orbital contents (2) interference with the function of the inferior rectus and inferior oblique muscles due to an extrusion of the orbital contents into the maxillary sinus and the incarceration of orbital structures into the fractured floor of the orbit.

As previously noted (see Chapter 9) depression of the orbital floor occurs by one of three mechanisms (1) downward displacement of the zygoma and separation of the frontozygomatic junction (2) fracture of the thick orbital rim and comminution of the thin "weak area" of the orbital floor and (3) "blow out" fracture through the "weak area" the result of increased intraorbital pressure from a direct blow to the orbital contents.

Comminuted fractures and fractures complicated by sequestration of bone have been responsible for loss of bone which varies in extent from small sections of the orbital margin to loss of the entire orbital floor Such conditions may be associated with extensive loss of the maxilla and zygoma extreme ptosis of the eyeball occurs when the entire floor of the orbit is missing

A deepening of the superior palpebral fold is indicative of ptosis of the eyeball. The *characteristic deformity seen in Figure 603* is present when a major portion of the floor has been destroyed. One may occasionally note the outline of the levator muscle beneath the skin The extent of ptosis of the orbital contents may be estimated by the ruler test (Fig 605) Recession of the insertion of the septum orbitale causes the lower lid to be drawn backward and downward (Fig 604) such a condition has been incorrectly attributed to loss of eyelid skin.

Loss of the inferior orbital rim causes the eyeball to appear prominent (pseudoexophthalmos) owing to an increase in the vertical width of the interpalpebral fissure This condition is evaluated by comparative measurement of the height of the interpalpebral distance (1) with the eyes in the primary position (2) with the gaze elevated. and (3) with the eyes in the position of *depression*

Diplopia is the most distressing consequence of ptosis of the globe Correction of diplopia by reconstruction of the orbital floor with bone grafts is required in such cases.

Diplopia is also observed in "blow out" fractures and is caused by *the incarceration* of the tissues of the orbit including the

FIG 603 Reconstruction of the maxilla, zygoma and floor of the orbit by bone grafts.

A. Deformity resulting from resection of the maxilla and zygoma for carcinoma of the left maxillary sinus. Note the ptosis of the contents of the left orbit, deepening of the superior palpebral sulcus and retraction of the lower lid, as illustrated in C to E of Figure 602.

B. Appearance of patient after surgical reconstruction by bone grafts illustrated in Figs. 610 and 611 (From J M. Converse and B. Smith, Plast. & Reconstruct. Surg 5 426 1950)

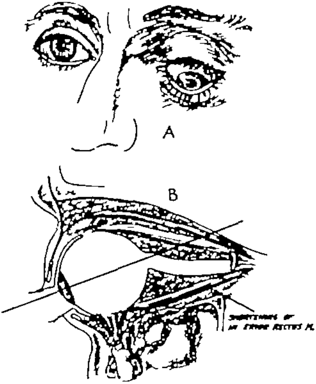


FIG 604 Orbital deformity due to loss of the floor of the orbit.

A. Note the deepening of the superior palpebral fold due to ptosis of the orbital contents and the downward rotation of the eyeball due to incarceration of the inferior rectus muscle

B Drawing representing adhesions between the orbital contents and the bone fragments depressed into the maxillary sinus. The downward rotation of the eyeball is caused by adhesions and incarceration of the inferior rectus muscle.

(Figs. 604 and 605 from J M. Converse and B. Smith, Arch. Ophth. 44 1 1950)

inferior rectus, into a rent in the weak area of the orbital floor Limitation of upward rotation of the ocular globe is the diagnostic sign of this type of diplopia.

TESTS FOR DIPLOPIA. Since diplopia is a subjective condition the tests for its analysis depend upon the co-operation of the patient Subjective results from tests for diplopia must therefore be correlated with objective findings for proper diagnosis and treatment.

The Occlusion Test. Alternating a small cover in front of the eyes permits the patient to advise the examiner about what happens to the double image. Persistence of the double image when one eye is occluded means that diplopia is monocular rather than binocular disappearance of one image indicates binocular diplopia The image seems to move when the occluding apparatus is rapidly alternated from one eye to the other The apparent motion of the image is opposite to the direction of movement of the eyeball This test enables the examiner to observe the motion of the eye and to draw conclusions as to whether the deviation is horizontal or vertical or a combination of the two The amount

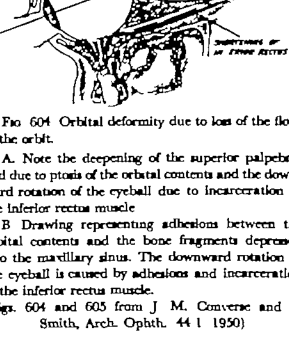


FIG 605 The ruler test. The horizontal line reveals the ptosis of the right orbital contents.

of ocular deviation in the various fields of gaze may be estimated by testing with prisms Interpretation of the findings leads to a presumptive diagnosis as to the specific

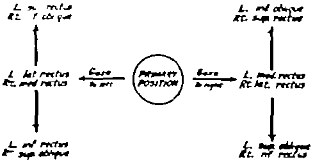


Fig. 606. Schematic representation of the action of the yoke of the eye muscles in various positions of gaze.

(Figs. 606 and 607 from B. Smith, Plast. & Reconstruct. Surg. 20:318, 1957)

muscles involved. The occlusion test is reliable because it offers both a subjective and objective analysis (Fig. 606).

The Red Glass Test. A simple red filter placed in front of the one eye helps the patient to describe the displacement of images. Although a diplopia field may be plotted by means of this test, it is not as accurate as either the cover or occlusion test. The red glass maybe modified so that its image is perceived as a line rather than a point. This modification is known as the Maddox rod test and has the advantage of separating the horizontal from the vertical displacement by observation of the line in the vertical and horizontal meridians respectively.

Other Tests. Numerous mechanisms such as Polaroid filters, complicated machines, perimeters and other orthoptic devices aid in the refinement of diplopia analysis. These complicated tests are unnecessary in the average case of diplopia resulting from orbital fracture.

Monocular Diplopia

Monocular diplopia is a one-eyed phenomenon and consequently represents a visual rather than an oculorotary disturbance. If functional, the condition is managed as any other psychosomatic disorder. Organic monocular diplopia is caused by any alteration or obstruction along the visual axis which is conducive to duplication or multiplicity of monocular retinal images. Abrasions of the cornea, opacities in the cornea, lens or transparent media, abberations in the iris diaphragm, displacement of the lens, disturbance of the retina and choroid and other similar conditions may contribute to monocular diplopia. Organic monocular diplopia is purely an ophthalmological problem.

Binocular Diplopia

Binocular double vision is caused by images upon non-corresponding retinal points in both eyes. These images, transmitted to consciousness under normal circumstances, are the fused images from corresponding points of the retina. Essentially, the sharply focused fused images received by the cerebral cortex from the macular areas are those registered in the area of consciousness. Images received from non-corresponding points on the peripheral retina are poorly perceived in consciousness and are used as a means of orientation rather than attentive fixation.

A normal person can observe the diplopia arising as a result of peripheral images being focused upon non-corresponding retinal points. Most of us are not plagued with this diplopia (physiologic diplopia) because we have learned to suppress the peripheral images. Ordinarily we see but a single image; if one tries, however, *physiological diplopia* may be observed. This simple experiment is conducted by holding a pencil in a central position about two feet in front of the eyes and focusing across the room. The pencil is seen double. Likewise, focusing on the pencil and observing objects across the room produces a double image of the distant objects.

An occasional patient discovers *physiological diplopia* and suffers from its symptoms until explanation and reassurance lead back into the normal mechanism of peripheral visual suppression. Suppression is a psychological mechanism by which the individual learns to ignore ocular images. Suppression may be central, peripheral or both. Suppression is one means by which

a person may learn to overcome double vision caused by extraocular muscle imbalance.

Binocular diplopia due to deviation of the visual axes, secondary to extraocular muscle imbalance is the diplopia usually encountered in the management of orbital fracture. Ocular deviation and diplopia resulting from organic muscle changes are caused by conditions which include edema hemorrhage laceration fibrosis and disturbances in nerve supply and displacement of the eyeball Deviation may also follow diminution of visual acuity since the normal mechanism of fusion is not sufficiently stimulated to bring about binocular vision. Ocular deviation may also occur in the presence of good vision in each eye as a result of a defect in the fusion mechanism.

Individuals with normal vision and a normal fusion mechanism become conscious of double vision when the visual axes are carried beyond the range of normal fusion Even slight restriction of extraocular muscular activity in orbital fractures may result in diplopia. Individuals with defective vision or poor fusion tolerate extreme limitation of ocular motility without diplopia. Since the range of vertical fusion is much less than that of horizontal fusion the binocular mechanism is less tolerant to vertical imbalance than to horizontal imbalance

Horizontal deviations frequently develop secondarily to the vertical deviation this is partially due to direct involvement of the horizontally acting muscles Secondary actions of the vertically acting muscles also are influential in the superimposed horizontal deviation

Fractures of the orbital floor are frequently accompanied by restricton of elevation in the field of action of the homolateral superior rectus muscle. This is not usually due to direct involvement of the superior rectus but is indicative of the inelasticity of the inferior rectus. In early cases, we have found the inferior rectus and inferior oblique muscles incarcerated

Fig 607 Characteristic restriction in elevation and depression of the eye in fracture of the right orbit.

in the fracture site In late cases these muscles and surrounding tissues become so incorporated by fibrous tissue that the involved eye cannot be elevated (Fig 607) The shortening and fibrosis in these muscles may be so great that the eye cannot be elevated even when a forceps is applied to the tendon of the inferior rectus This test known as the traction test, affords a means of differentiating contracture or fibrosis of the inferior rectus from weakness or paralysis of the superior rectus. It is also an external means of diagnosing incarceration of the inferior rectus in early posttraumatic cases.

The fracture site affects the extraocular muscles by such factors as direct trauma, edema ecchymosis herniation displacement and incarceration The degree of injury may be such that spontaneous recovery is not possible. One of the reasons for the vulnerability of the inferior rectus and inferior oblique muscles is the intimate anatomical relationship of these structures to the common fracture site. The inferior oblique muscle arises from the orbital floor near the temporal margin of the lacrimal groove. It passes posteriorly and toward the temple superficial to the belly of the inferior rectus muscle and inserts into the sclera behind the equator deep to the belly of the lateral rectus. The sheath of the inferior rectus muscle is loosely attached to that of the inferior oblique.

The extent of injury beyond which spontaneous recovery is impossible is difficult to

determine It is our feeling that all depressed fractures of the orbital floor should be surgically reduced and maintained by mechanical means.

The patient may not recognize diplopia early if the eye is temporarily closed by edema of the lids, by dressings, or because of intraocular injury Diplopia may appear only after edema has disappeared hematoma becomes absorbed, and scar tissue contraction begins to exert its effect Each case presents an individual problem and repeated diagnostic studies are necessary both before and after bone surgery

Enophthalmos and Exophthalmos

Enophthalmos is a frequent accompaniment of a fracture of the orbital floor due to enlargement of the orbital cavity or escape of fat into the maxillary sinus (see Fig 285 Chapter 9) A temporary exophthalmos is observed in the acute stage, due to orbital hematoma a relatively increased protraction of the eyeball pseudoexophthalmos, may also be due to the loss of the infraorbital margin of the posteriorly displaced maxilla true exophthalmos may result from diminution in the size of the *orbit due to backward displacement and* overlapping of fractured bone fragments The excess of orbital fat in an undersized cavity also causes a protrusion of the eyeball

Roentgenographic Studies

Roentgenographic examination offers additional orbital information and employs five projections the Caldwell view Waters view lateral view the view of the optic canals and the base view these are discussed in Chapter 15

Reconstruction of the Floor of the Orbit by Bone Grafts

When bone has been lost through sequestration or radical surgical measures, or when the bone is so comminuted that it cannot be replaced restoration of the or*bital floor* by bone grafts is the method of choice (Converse 1944 Converse and Smith, 1950)

Various types of implants have been utilized to restore the continuity of the orbital floor and to raise the depressed contents. Judging from our experience and from other reports (White 1948 DeVoe 1950), implants of foreign substances (vitallium, tantalum acrylic resins glass wool) tend to become extruded. Preserved cartilage homografts are slowly invaded by host connective tissue and vessels and absorbed autogenous cartilage which was extensively used by LaGrange (1918) remains intact but has a tendency to curl Bone presents a number of advantages It becomes consolidated with the adjacent bone, provided that the graft is placed in contact with healthy bone stripped of its periosteum it preserves its original size and shape it is readily available as autograft or homograft

The skin of the eyelid is raised over a distance of a few millimeters below the incision a cutaneous incision is made in one of the folds of the eyelid (Fig 608*B*) fibers of the orbicularis oculi muscle are split (Fig 608*B*) and the anterior rim of the *depressed orbital floor is exposed (Fig* 608*C*) The periosteum is incised and the orbital contents are raised with the periosteum from the orbital floor (Fig 608*D*). The eyeball is then elevated to the desired position by means of a retractor and a bone graft of suitable size and thickness is placed over the depressed floor (Fig 608*F* *F*) In raising the ptosed eyeball the operator is guided by comparing its position with the unaffected eyeball and also by the degree to which the superior palpebral fold has been corrected *A block of cortical* and cancellous bone is used and any crevices or dead spaces remaining on the side of or beneath the graft are filled with small chips of cancellous bo

Defects fl bit are bridged The peripl s are

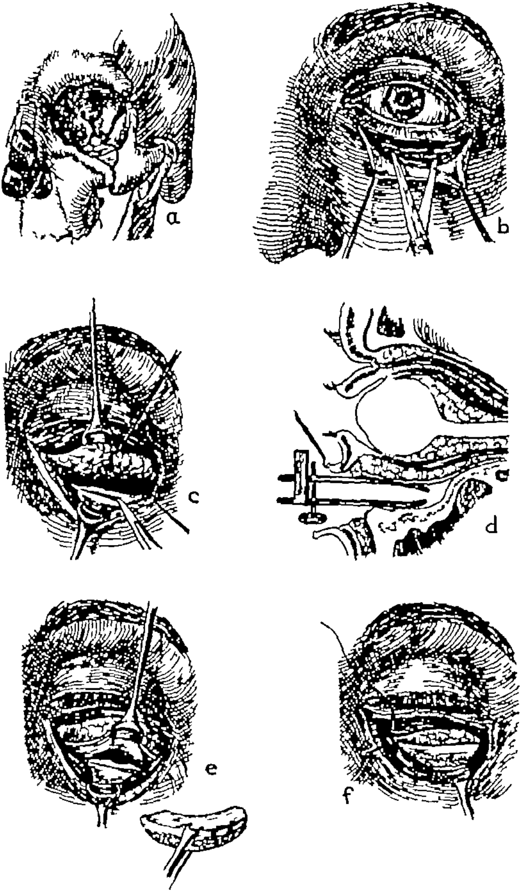


Fig 608. Drawings illustrating the reconstruction of the floor of the orbit by bone graft.
A. Illustrating the downward displacement of the floor of the orbit.
B. The fibers of the orbicularis oculi muscle are split
C. The periosteum is incised.
D The eyeball is raised by a double-bladed calibrated instrument.
E. Iliac bone is prepared for introduction over the floor of the orbit.
F The bone graft is shown in position
(From J M. Converse, Arch. Ophth., 31 323 1944)

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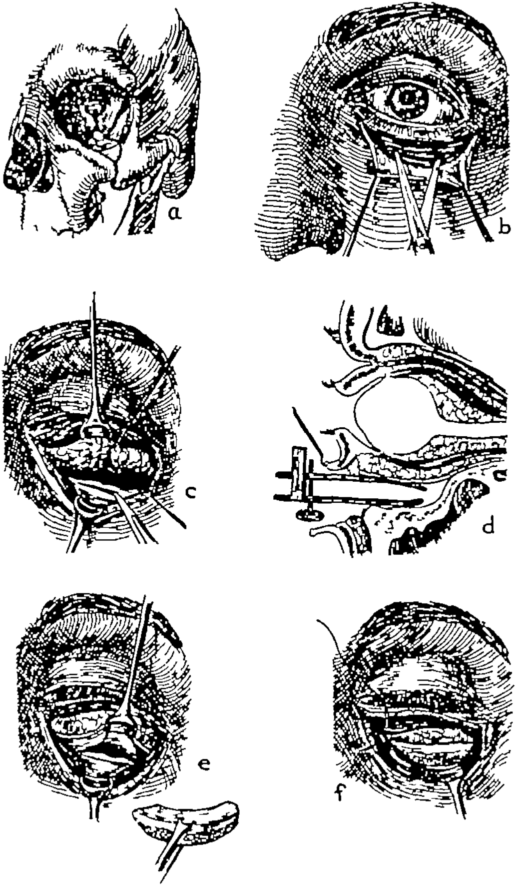
Defects in the floor of the orbit are bridged by means of a bone graft. The peripheral limits of the orbital contents are



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(From J. M. Converse, Arch. Ophth. 31:323, 1944)

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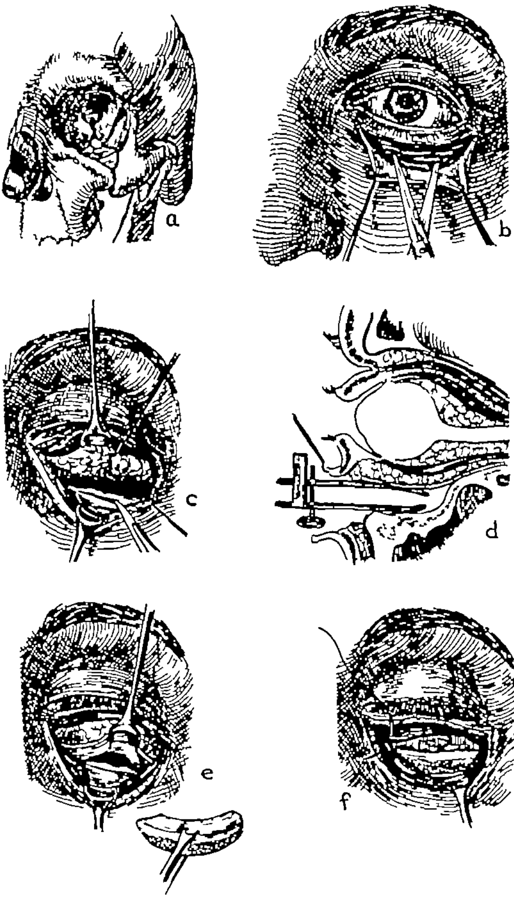

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F. The bone graft is shown in position.
(From J. M. Converse, Arch. Ophth. 31:323, 1944)

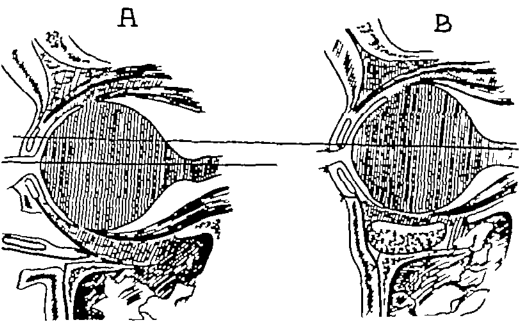

FIG 609

A. Freeing of the septum orbitale by elevation of a flap of periorbita.
B. The flap is placed in front of the bone graft. The retracted lower lid is thus freed.

exposed and freed from the underlying scar tissue to raise the eyeball to the desired position The edges of the bony defect are exposed by elevating the periosteum the bone graft is then wedged between the edges of the defect Accessory grafts of cancellous bone chips may also be used to complete the *reconstruction. Such defects of the floor* of the orbit have varied in size the entire orbital floor was reconstructed in two of our cases.

In cases of recession of the septum orbitale it is necessary to raise a flap of the periorbita this flap which is a blend of periorbita and posterior extension of the septum orbitale, is turned forward and placed in front of the inserted bone graft (Fig 609) thus releasing the downward and backward pull of the lower lid

A pressure dressing is applied for a period of at least five days after suture of the orbicularis oculi fibers and skin and a mattress suture to provide temporary interpalpebral fixation

The approach through an external incision in the lower lid offers the best exposure of the orbital floor In one of our cases the defect involved the entire half of the maxilla and the zygoma requiring extensive bone grafting (Figs. 605 610 and 611)

Figure 612 shows a patient in whom a reconstruction of the floor of the orbit was required to correct diplopia

ADDITIONAL SURGICAL MEASURES. After the restoration of bone contour subsequent procedures may *include surgical correction* of the extraocular muscles and lids. At least six months should elapse after bone surgery before surgical measures on the oculorotary structures are initiated If nerve injury is a factor in the heterotropia at least one year from the time of injury should be allowed for spontaneous nerve regeneration before compensation by extraocular muscle surgery is planned.

Should diplopia persist after all bone work has been completed the condition should be treated conservatively until further improvement ceases. As a rule maximum spontaneous recovery occurs in less than six months. Frequent measurements of muscle deviation are necessary to evaluate *progress and diagnose early* muscle contractures. Any area of single binocular vision should be used exercised and encouraged regardless of the field. To utilize

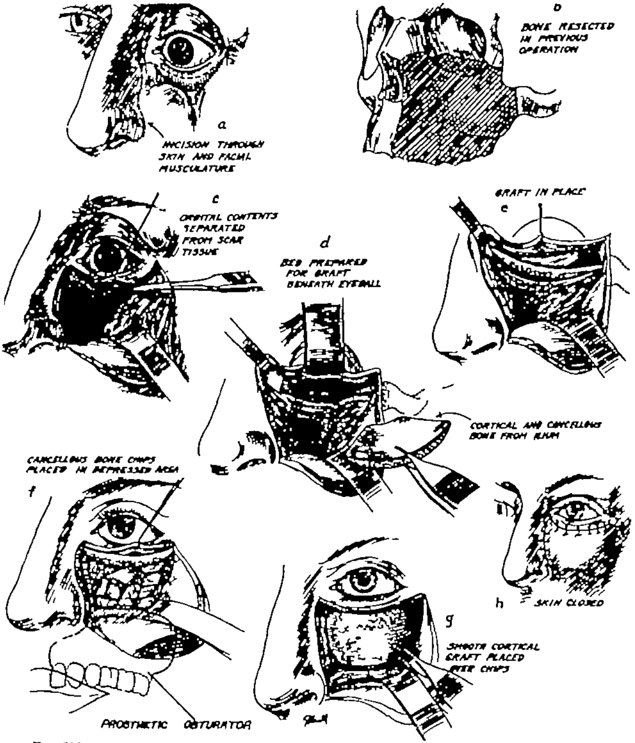

FIG. 610. Technique of reconstruction of the maxilla and zygoma by bone grafts (see Fig 603)

A. Line of incision outlining cheek flap.

B. Shaded area shows the extent of the bone resected.

C. The cheek flap has been reflected. The orbital contents are freed from binding scar tissue.

D The orbital contents are raised. After subperiosteal exposure of the frontal process of the maxilla and of the zygomatic arch, a bone graft is prepared for insertion.

E. Bone graft in position, restoring the floor of the orbit.

F The depressed area is filled with cancellous bone chips.

G An overlay bone graft restoring contour is placed over the bone chips.

H. Suture of the edges of the skin flap to the edges of the defect has been completed.

(Figs. 610 and 611 from J M. Converse and B. Smith, Plast. & Reconstruct. Surg 5·426, 1950)

FIG 611 Roentgenogram taken two years and six months after bone grafting shows that the grafts restoring the left maxilla have become consolidated to the zygomatic arch laterally and to the frontal process of the maxilla medially (see Fig 603)

the single field of vision, the patient may be forced to modify the normal head attitude and posture

In terminal muscle surgery an attempt should be made to move the field of single binocular vision into a central position Not only is this a convenience to the patient but it corrects head posture and relieves aches and pains in the neck muscles One of our most grateful patients was a woman with a malunited orbital fracture and a complaint of pain in the back of her neck. For forward single vision she was forced to tilt her head slightly backward From a study of the extraocular muscles, it was decided that the inferior oblique muscle of the sound eye should be recessed. The operation was performed despite her skepticism. The head posture was corrected and the pain in the neck disappeared immediately This case demonstrates that operation may be performed upon the sound as well as the unsound eye, if the double images can be brought closer together in the proper field of gaze

Corrective lid-supporting surgical therapy (see Figs. 582 and 581) is the final procedure if blepharoptosis complicates the condition and suture of the levator muscle has failed.

The correction of interpalpebral widening is deferred until the bone graft has solidified and lymphatic channels and circulation have become re-established. The period of such tissue adjustment is considered to be not less than eight weeks. The surgical correction of interpalpebral widening by lateral tarsorrhaphy eliminates the appearance of the fixed stare and pseudo-exophthalmos.

Late Treatment of Enophthalmos

The treatment of traumatic enophthalmos is a preventive one (see Chapter 9).

FIG 612 Reconstruction of the floor of the orbit by a bone graft

A Photograph showing ptosis of the left eyeball due to loss of orbital floor with ectropion of the lower lid.

B. Result obtained by elevation of the floor of the orbit by a graft from the ilium by technique shown in Figure 608 and repair of the lower lid

(From J M Converse Arch Ophth 31 323 1944)

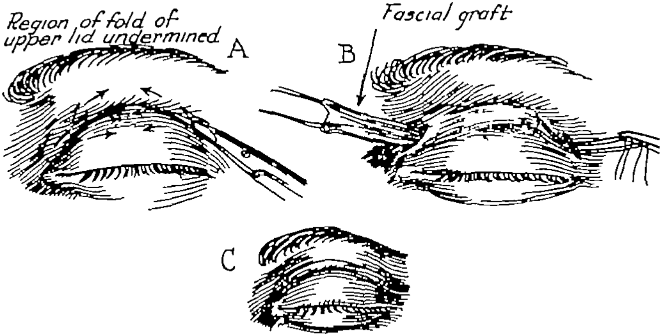

FIG 613 Filling of depression in supratarsal fold by fascia lata graft

A. Small incision made at the lateral aspect of the tarsal fold the skin over the fold is undermined superficially

B. The fascia lata graft is introduced into the subcutaneous pocket by means of guide sutures.

C. Fascia lata graft in position.

Late treatment of severe enophthalmos is often unsatisfactory because of the shortening of the intraorbital structures Some improvement in the appearance of the patient can be achieved by restoring the supratarsal sulcus by fascia lata (Fig 613) or dermal graft. Some degree of correction of the enophthalmos is obtained by subperiosteal elevation of the orbital contents from the floor of the orbit and placing bone grafts along the orbital floor in its posterior portion avoiding injury to the optic nerve Bone grafts may also be placed along the lateral wall of the orbit. The diminution in size of the orbital cavity tends to protrude the ocular globe As much as 9 mm exophthalmometric improvement has been obtained in cases in which fascia lata was placed deep in the orbital cavity between the periorbita and the bony floor of the orbit (Cole Smith & Converse 1959)

Extraocular Muscle Injury in Orbital Fractures

Diplopia may be a transient condition resulting from hemorrhage or edema of the orbit, or it may become permanent from cicatrization due to muscle injury damage to the nerve supply or displacement of the bony orbital walls.

The superior oblique pulley is often damaged due to its proximity to the surface and contact with the bone The sixth nerve may also be traumatized in orbital injuries, resulting in paralysis of the lateral rectus muscle and limitation of ocular abduction A period of six months should elapse to allow for recovery before corrective muscle surgery is undertaken Prism vergence tests

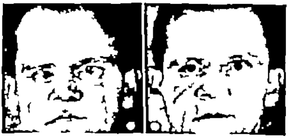

FIG 614

A. Extraocular muscle disturbance due to intraorbital damage suffered in comminuted fracture of the bones of the middle third of the face.

B Result obtained by extraocular muscle surgery

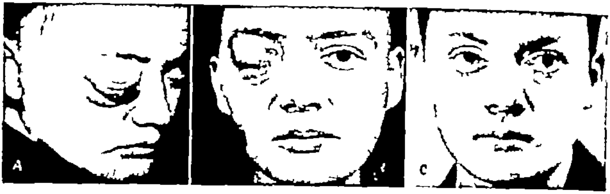

FIG 615. Traumatic pulsating exophthalmos
A. Patient with exophthalmos due to traumatic arteriovenous aneurysm of the right cavernous sinus
B. Appearance of patient after successful ligation of the common carotid artery on the right side.
(From B. Smith, Tr Am. Ophth. Soc. 41.673 1952)

should be made and if spontaneous recovery has not occurred surgical treatment must be considered. In lateral rectus paralysis, strips of the superior and inferior rectus muscles may be transplanted to the tendon of the lateral rectus this procedure is usually combined with recession of the insertion of the medial rectus. Recession of the medial and lateral rectus muscles in other cases can be achieved without disturbing the vertical muscles (Fig 614)

Fortunately the compensatory power of the binocular fusion mechanism tends to overcome diplopia Injury to the oculorotary muscles is severe enough in other cases however to render ineffective the compensatory power of the binocular fusion mechanism

Pulsating Exophthalmos

Pulsating exophthalmos may occur after severe injuries due to a defect in the orbital roof and the direct transmission of the pulsation of the brain through this defect it may also be due to posttraumatic arteriovenous fistula. In no part of the body other than the cavernous sinus does an artery actually traverse a venous channel and lend itself so readily to an arteriovenous aneurysm

Pulsating exophthalmos is not always manifest upon ordinary inspection It may be felt by the fingers only when the globe is pressed backward into the orbit.

The patient may suffer from pain on the same side as the lesion there is a subjective bruit, homolateral involvement of the third fourth fifth and sixth cranial nerves and manifest pulsating exophthalmos (Fig 615)

The intermittent roar heard by the patient is heard by the examiner as a systolic bruit. Digital compression of the carotid artery on the subjective and objective transmission of the murmur frequently serves as an aid in determining the side of the lesion If compression of the carotid cannot be tolerated for a five or ten minute period (the Matas test) serious damage of the brain may be anticipated after surgical occlusion of the internal carotid artery

Ligation of the common carotid is less hazardous than ligation of the internal carotid because of the collateral reverse flow of blood from the external carotid. Ligation of the common carotid is followed by immediate improvement in properly selected cases a gradual return of some of the symptoms begins within twenty four hours. Permanent improvement occurs when thrombosis begins during the period of reduced intracranial arterial pressure

Dandy suggested treating the condition by placing a silver clip on the intracranial portion of the internal cartoid artery immediately before it divides This procedure isolates the fistula but it is not ideal because the internal carotid gives off the

ophthalmic artery between the two points of ligation It may be necessary to ligate the collateral branches of the ophthalmic artery as a final stage to complete the cure

Resurfacing the Orbital Cavity

The correction of extensive defects which result in the loss of the orbital contents depends upon the judgment of the surgeon Such a condition has been remedied by resurfacing the orbital cavity with a flap in order to cover the bone and partly fill the defect (see Figs. 899 to 901 Chapter 23)

DEFORMITIES OF THE ZYGOMATIC REGION

The zygomatic or zygomaticomaxillary area located in the lateral portion of the middle part of the face, is formed by a skeletal framework consisting of the zygoma and the zygomatic process of the maxilla these bones are covered by the origins of the masseter the zygomatic head of the quadratus labii superioris and zygomaticus muscles the lateral portion of the orbicularis oculi muscle, the subcutaneous tissues and the skin

The prominence of the upper part of the cheek is formed by the zygoma loss of the prominence due to malunited fracture of the zygoma results in a noticeable deformity (Fig 616) In addition to deformity in such fractures functional disturbances may involve the orbit because the orbital process of the zygoma forms a part of the lateral wall and the floor of the orbital cavity Functional disturbances also occur in fractures of the zygomatic arch for

A  B

FIG 616. Malunited fracture of the zygoma Contour restoration by bone grafting through the intraoral approach.

A. Depression over the right zygomaticomaxillary area resulting from malunited fracture following fist blows.

B. Restoration of contour obtained by iliac bone grafts placed over the right maxilla and zygoma after elevation of the periosteum. The infraorbital nerve was preserved Immobilization of the transplants was obtained by a pressure dressing.

(From J M. Converse, Plast. & Reconstruct. Surg., 6:295 1950)

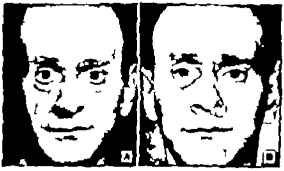

FIG 617 Malunited fracture of the zygoma Contour restoration by bone grafts.

A. Shows the type of deformity obtained when the fracture results in a rotation of the zygoma with a backward displacement of the maxillary process of the zygoma and a lateral displacement of the temporal process of the bone This displacement produces a depression in the infraorbital region.

B. Result obtained by contour restoring bone grafting through the intraoral approach.

(From J M. Converse and R. M Campbell, S. Clin. North America, 34 375, 1954)

the displaced bone may press against the coronoid process of the mandible thus interfering with mandibular function

There are two types of depression deformities of the zygoma. In the first, the maxillary process of the zygoma and the zygomatic process of the maxilla are depressed into the maxillary sinus and the fractured bone is dislocated laterally the resulting deformity is seen as a depression in the infraorbital region of the cheek (Fig 617) In the second the zygoma is depressed causing a loss of cheekbone prominence and a generalized appearance of flatness (Fig 616) Because of relaxation of the musculature caused by the downward displacement of the bony origins of these structures, certain additional effects such as accentuation of the nasolabial fold drooping of the upper lip and deviation of the lip to the unaffected side also occur

Treatment of Malunited Fractures of the Zygoma

Two alternative methods of treatment should be considered in cases of malunited fracture of the zygoma which result in deformity The first is to replace the displaced bone after osteotomy is performed and the zygoma is freed from its surrounding bony attachments. The technique of this procedure has been described earlier in Chapter 9 and is indicated in recently malunited fractures when the zygomatic process of the frontal bone has been separated from the frontal process of the zygoma. After the zygoma has been mobilized, the continuity of the lateral wall of the orbit is re-established and the bones are wired together Osteotomy also permits raising the depressed zygomatic arch and relieving the pressure over the coronoid process of the mandible

Osteotomy of the malunited zygoma is not without danger because the force required to sever the bony connections of the zygoma to the surrounding bones may

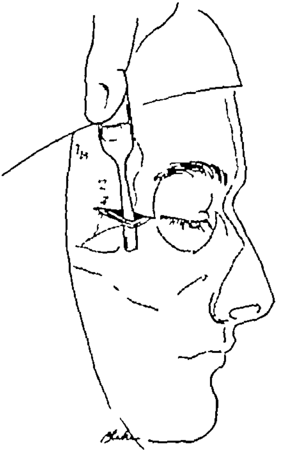

FIG 618. External approach for the introduction of contour restoring bone grafts over the malunited zygoma. An incision placed in one of the folds lateral to the orbit provides an easy access to the zygoma and does not result in any visible scar

cause radiating fractures and hemorrhage in the vicinity of the optic nerve. Blindness is an occasional complication of fracture of the zygoma. Gordon and Macrae (1950) reported blindness following reduction of a recently fractured zygoma

When little or no functional disturbance has occurred, although loss of the cheek prominence requires correction contour restoration is achieved by bone grafting over the malunited zygoma. Bone grafts were employed for the restoration of zygomatic contour by Murphy (1915) The treatment is a simpler technical procedure than osteotomy and replacement of the impacted malunited bone

The Extraoral Approach

In considering restoration of zygomatic contour by bone grafts if the depressed area extends laterally to the tuberosity of the zygoma, an external incision is made horizontally in one of the natural skin folds lateral to the outer canthus (Fig 618) this leaves only an inconspicuous scar after healing, avoids filaments of the seventh nerve and offers a satisfactory exposure for the introduction of the bone graft. The periosteum over the depressed zygoma is incised and raised and a suitably shaped iliac graft of cortical and cancellous bone is inserted to restore cheekbone contour

An incision in the temporal area similar to that employed for reduction of the fractured zygoma may also be employed for the introduction of contour restoring bone grafts

The Intraoral Approach

The intraoral approach is an excellent choice for exposure of the *malunited* zygoma for osteotomy and replacement and also for the introduction of *contour restoring* bone grafts. Such a procedure permits a direct view of the maxilla and zygoma from the pyriform aperture medially to the infraorbital margin superiorly The incision in the oral mucosa of the lip is placed lateral to the frenulum on the affected side above the vestibular cul-de-sac (see Fig 281 Chapter 9) The periosteum is incised and elevated after dissecting the mucosa from the orbicularis oris muscle, thus exposing the defect. Wide exposure of the maxilla is obtained the zygoma may be approached by extending the periosteal elevation laterally The infraorbital nerve and vessels are avoided by carefully raising the periosteum around the neurovascular bundle and preserving its attachment to the elevated soft tissues. Raising the soft tissues with retractors results in good exposure of the maxilla and zygoma The bony defect may then be inspected under adequate lighting

Most defects are prepared by one main bone graft consisting mostly of cancellous bone, which is placed over the defect. Additional fragments of cancellous bone are packed beneath and around this onlay of bone in the intervening crevices to further improve the bony contour The vestibular incision is then sutured with 4-0 plain catgut sutures and an external pressure dressing is used to immobilize the grafts The eyelids should be sutured to avoid corneal abrasion under the pressure dressing Further dressings are unnecessary following fixation of the grafts, which usually occurs as early as one week postoperatively

Smaller defects of the maxilla above the alveolar process, in the region of the anterior wall of the maxillary sinus or the pyriform aperture can also be readily repaired by this technique. Although the lower rim of the orbit may be approached through the oral route, it is best exposed by an incision along the margin of the lid, by splitting the fibers of the orbicularis oculi muscle.

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DEFORMITIES OF THE NOSE

Deformities of the nose requiring reconstruction include a number of disfigurements due to scars or loss of tissue involving the soft structures covering the nose. Injuries affecting the underlying skeletal structure, the lining of the nasal vestibules and fossae, and problems attending partial or complete loss of nasal structure are discussed in this chapter.

The anatomy of the external nose is described in Chapter 8.

DEFORMITIES OF THE SKIN COVERING THE NOSE

Superficial Scars

Scars of the skin of the nose, when linear and smooth, are barely visible; scars resulting from poorly sutured wounds, however, are conspicuous, particularly when they cause notching of the alar border or distortion of the nasal tip. Approximation of the borders following excision of the scars results in a fine linear scar line. Such a line is more easily attained toward the root of the nose, for in this area the skin is loosely attached over the bony framework. Toward the tip and alae of the nose the skin is thicker, containing many sebaceous glands; it is firmly attached to the underlying cartilaginous structures. Even a linear scar in this area produces notching of the alar border unless the stepping procedure is followed (Fig. 619). Superficial scars toward the root of the nose, necessitating the excision of an appreciable area, can be repaired satisfactorily; at the tip and alae of the nose, however, even small defects are difficult to close without distortion. The ala may be retracted upward by a scar. Figure 620 shows a method of correcting such a contracture by Z-flaps.

Loss of a considerable amount of skin, as in burns, results in a telescoping of the alar cartilages over the lateral cartilages (Fig. 621). In severe retraction of the alae the vibrissae of the nasal vestibule are conspicuous and the columella, relatively fixed by the cartilaginous septum, appears to protrude downward. In such instances, upward retraction of the alar border gives the appearance of partial loss; examination, however, often reveals a displaced but intact alar cartilage. Such distortions may result from simple loss of skin without concomitant injury to the underlying framework. Resection of the scar permits the return of the cartilages to their normal positions, thus disclosing the true extent of the defect.

Defects Repaired by Local Flaps

Local flaps of skin have limited use and are usually employed in the repair of small defects of the looser tissue covering the upper portion of the nose; such defects are corrected by rotation flaps. In the lower portion of the nose the barter principle is sometimes used advantageously; a flap is shifted from the upper to the lower portion of the nose and a free graft or skin flap is applied to the secondary defect (Figs. 622 and 623). Local flaps of nasal tissue can be used for repair of small defects of the

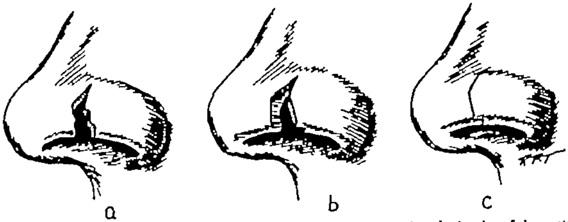


Fig 619 Application of the halving and stepping technique when suturing the border of the nostril.

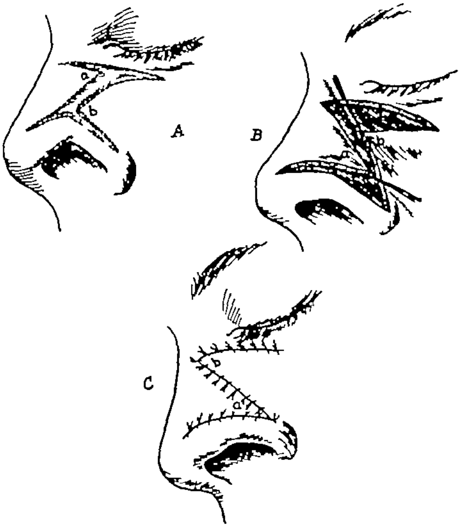


Fig 620. Diagrams showing correction of scar contracture of the nose by Z-flap method
A. Outline of scar for excision.
B. Transposing Z-flaps after scar excision.
C. Z-flaps sutured in transposed position.

upper part of the nose these however may result in distortion of the tip or alae of the nose when employed in the lower portion.

In some instances, if the bony and cartilaginous structures of the nose are reduced in size thereby increasing the amount of available skin the defect can be closed by local flaps sutured without tension

FIG 621 Scar contracture due to burns of the face

A. Photograph of patient showing upward displacement of the alae The illusion of tissue loss is caused by upward retraction.

B. Result obtained by liberation of the displaced alar cartilages and the utilization of a forehead flap for a new nasal covering

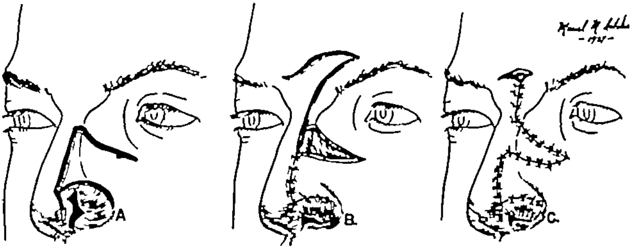


FIG 622. Repair of nasal defect by local flaps employing the barter principle

A Drawing showing the incision for the local flap.

B. The flap has been shifted downward and sutured disclosing the secondary defect.

C. *The secondary defect has been closed by a small forehead flap*

In suitable cases especially in elderly patients skin can be borrowed from the surrounding areas of the face without creating conspicuous additional scars. The methods for nasal skin replacement include a tongue-shaped flap from the nasolabial area an advancement flap from the cheek a skin graft or a flap from the median portion of the forehead (Fig 621 and 625)

Nasolabial Flap

The nasolabial flap (Fig 626) is useful to provide skin replacement for the nose particularly in older individuals. The design of the flap is triangular with the apex below and the base of the triangle above Although the flap is designed in a retrograde fashion in relation to the blood supply the

A

B

Fig 623. Repair of nasal defect by local flaps

A. Photograph of patient showing notching of left ala.

B. Result obtained by technique shown in Figure 622.

(From V H Kazanjian, Tr Am. Acad. Ophth., and Otol 42.338, 1937)

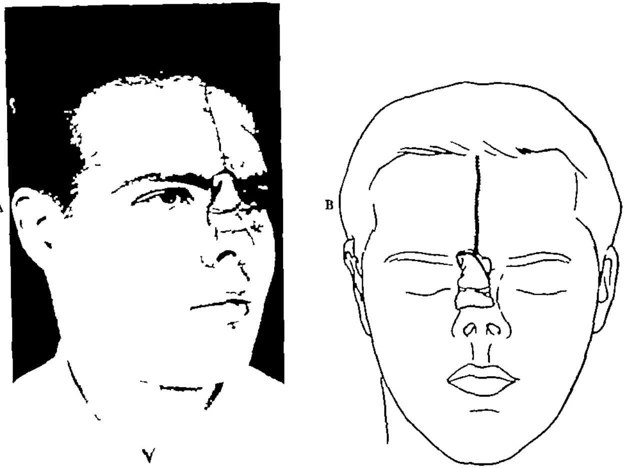


Fig 624 Technique of repair of nasal defect shown in Figure 625

A. Drawing showing the method of transposing a median forehead flap to the defect. The secondary defect of the forehead is closed by direct approximation.

B. Photograph showing the flap in position.

(Figs. 624 and 625 from V H. Kazanjian, Surg Gynec. & Obst., 83.37 1946)

FIG. 625. Defect of the nose repaired by forehead flap. Anterior and lateral views (*upper*) showing dense burn scars combined with depression over the dorsum of the nose. Postoperative photographs (*lower*).

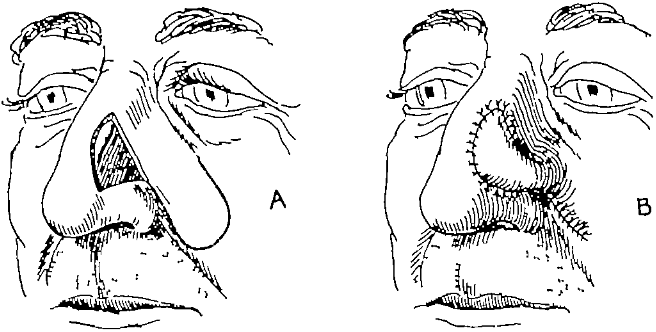


FIG 626 The nasolabial flap

A. Design of the nasolabial flap

B. When the donor area is closed the flap tends to assume a position closer to the nasal defect.

vascularization of the area is adequate to provide a good blood supply to the flap

The nasolabial fold is the area of junction between the tightly bound skin of the lip and the loosely bound skin of the cheek In males it also delimits the hair bearing area of the lip from the non hair bearing portion of the cheek. This fact is important in planning flaps taken from the nasolabial area If a hair-bearing portion of the skin is desired for reconstruction of the upper lip for example the flap should be outlined below the nasolabial fold. If non-hair bearing skin is required for the reconstruction of the ala of the nose or to resurface a skin defect of the nose, the flap should be taken from above the nasolabial fold in the non hair bearing area

After the nasolabial flap is raised, the secondary defect is closed by direct approximation the approximation is done without difficulty because of the looseness of the cheek tissues, not only in older individuals with loose tissues but also in children Closure of the donor site of the flap brings the base of the flap closer to the nose the flap thus assuming a position which facilitates its placement over the nasal defect without tension (Fig 626)

Cheek Advancement Flap

Skin defects of the lateral aspect of the dorsum of the nose may be covered by direct advancement of the skin of the cheek The looseness of the cheek tissues facilitates this advancement in older individuals the cheek skin may be advanced over the dorsum of the nose A straight advancement flap is outlined by making an incision in the nasolabial fold and another through one of the lower folds of the lower eyelid. The skin outlined in this flap is raised from the underlying subcutaneous tissue and is advanced over the nasal defect

Defects Repaired by Skin Grafts

Skin grafting the nose is a relatively simple procedure and is generally successful under proper conditions The length of time involved in hospitalization and convalescence is considerably shortened as compared with that required for the transfer of distant flaps. Good results are obtained by the use of full thickness retroauricular grafts skin may be obtained from behind both auricles if necessary or from the supraclavicular areas, for these areas offer skin of good color and texture. When skin from these areas is not available the graft is

A B C D

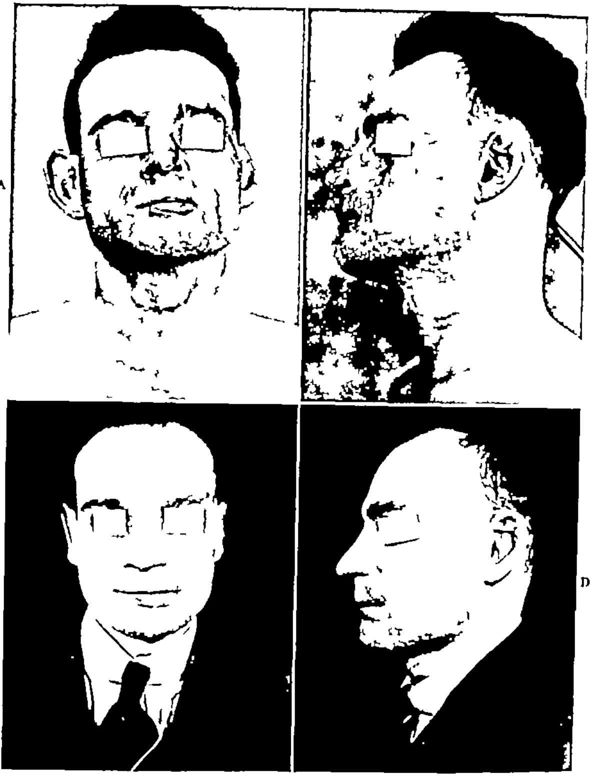


FIG. 627 Defect of the nose repaired with skin graft

A and B Photograph showing burn scars of the left side of the face and nose causing distortion of the left nostril

C and D The scars have been excised freeing the border and permitting the nostril to resume its normal position The defect following the excision of the scars was covered with a single postauricular full thickness skin graft Note the improvement in the appearance of the burn scars of the face due to the passage of time (18 months)

taken from more distant ones, for example, the inner aspect of the arm but the color match is poor The greater part of the outer covering of the nose can be resurfaced in one operation (Fig 627)

Difficulties are encountered in maintaining adequate pressure over the skin graft because of the shape and resiliency of the lower part of the nose pressure should therefore be applied carefully The nasal vestibules are packed firmly to prevent depression of the cartilages and uniform pressure is applied to the nasal pyramid. A satisfactory method for maintaining such an even distribution is obtained with the aid of a dental compound splint (see Fig 257 Chapter 8)

After the skin graft is sutured to the edges of the defect it is covered by a layer of Nylon or silk either of these fine-meshed materials are non adherent and are readily removed at the first dressing without disturbing the graft. A thin layer of absorbent cotton moistened with saline solution is placed over the graft and maintained by the splint the cotton dries and hardens forming a solid covering The cotton is again moistened at the first dressing and softened with saline solution in order to facilitate its removal Non-absorbent cotton soaked in mineral oil and wrung out is also a satisfactory dressing material for it is non adherent and easily molded over the graft.

Median Forehead Flaps

Distant flaps are indicated when local tissue for flaps is not available, when the recipient bed is unsuitable for a free graft or when the nature of the defect requires subcutaneous tissue as well as skin (Figs 621 624 and 625)

The donor areas of pedicled flaps in the order of their preference are the forehead and distant areas such as the arm neck, chest or abdominal wall Forehead skin for correction of nasal defects by a distant flap is preferred in most cases because the skin of the forehead harmonizes in color and texture with that of the nose and the rest of the face, and the forehead flap requires fewer operative steps. Generally only two stages are necessary for reconstruction The first stage consists of elevating the flap from its bed and suturing it over the defect, the unused part of the flap is returned to the forehead in the second stage. The remaining part of the forehead wound is then closed, either by direct approximation or by a skin graft.

DEFORMITIES OF THE SKELETAL FRAMEWORK OF THE NOSE

Corrective surgery of the external nose is required for both functional and esthetic reasons Deviation of the nasal pyramid following trauma may result in deformity and nasal airway interference nasal obstruction may also be due to depression of the dorsum of the nose and drooping of the nasal tip due to loss of septal support. The deviated septum requires correction and is an integral part of the nasal plastic procedure

Little faith in the success of purely corrective procedures was expressed by Nélaton and Ombrédanne in their textbook *La Rhinoplastie* published in 1904 "The surgeon could not pretend to correct a slight malformation. If a nose be slightly deviated or humped or show a slight saddle deformity—these are unfortunate defects but we do not believe that the correction of such defects can be achieved by surgery The development of nasal corrective operations nasal tip surgery in particular occurred later in the twentieth century

A review of the literature of the last decade of the nineteenth century and the early part of the twentieth century indicates that nasal corrective procedures were initiated mostly through externally placed *incisions*. The influence of Joseph who demonstrated the possibilities of such surgery through internally placed *incisions*, became a predominant factor in the first quarter of this century His teachings were collected in a

textbook published in 1931 and the Joseph technique for corrective surgery of the nasal tip has been widely used A description of a technique currently employed by Converse follows.

Anesthesia

Local anesthesia is commonly employed for corrective nasal plastic surgery the importance of correct preoperative medication must be emphasized

Both topical and infiltration anesthesia are required. Topical anesthesia is obtained by spraying cocaine (4 per cent) solution into the nasal cavities and applying cotton tipped applicators soaked in cocaine and adrenalin solution to the mucosa over the sphenopalatine ganglion and the anterior ethmoidal nerve branches (Fig 628). Infiltration of procaine and adrenalin completes the anesthesia hemostasis is obtained through the vasoconstrictive action of the adrenalin We use 2.5 to 3 cc. of 1 1000 adrenalin solution to 100 cc. of 1 per cent procaine solution and inject it at intervals during the operative procedure to avoid such side reactions as tachycardia, palpitations headache nervousness restlessness and anxiety Only the injections for anesthesia of the dorsum of the nose are employed for exposure of the nasal framework and modification of the profile the first two stages of the typical nasal plastic operation We usually employ a second series of injections for the osteotomy of the base of the lateral wall on the right side preceding the third operative stage Osteotomy of the base of the lateral wall on the left side requires a third series of injections additional anesthesia is indicated for an operation on the septum By following this method of local anesthesia the injection of large quantities of adrenaline is avoided and anesthesia is provided immediately before each successive step of the operation Adequate sedation and a high concentration of adrenalin plus careful dissection all contribute toward the control of hemorrhage during the operation

In the occasional patient who reacts unfavorably to local anesthesia and in children general anesthesia administered by tracheal intubation is preferred to avoid the passage of blood into the trachea General anesthesia results in an increase of bleeding during the operation Although hemorrhage is eliminated by the use of controlled hypotension the procedure increases the attending risks of an operation so satisfactorily performed under local anesthesia

Submucous Resection of the Nasal Septum

Submucous resection of a deviated nasal septum is one of the most satisfactory procedures in rhinology when indicated. Removal of an obstructing nasal septum almost always results in an improvement of the airway and relief of most of the symptoms that are associated with the obstruction

The submucous resection of the nasal septum described originally by Freer (1902) remains the basis of methods for straightening the nasal septum. Many modifications of this original technique have been employed.

Novocain-adrenalin solution is infiltrated beneath the mucoperichondrium to elevate the mucoperichondrium from the cartilage and to provide hemostasis (Fig 629 A B C) A short beveled No 18 needle is used for infiltration beneath the mucoperichondrium this large bore needle is of assistance because considerable pressure is sometimes required to elevate the mucoperichondrium In the badly traumatized nose where fibrous tissue has replaced a hematoma of the septum difficulty may be experienced in elevating the mucoperichondrium by the injection method

Most deviated septa show the greatest deviation at the junction of the septal cartilage and the perpendicular plate of the ethmoid The septal deviation may affect

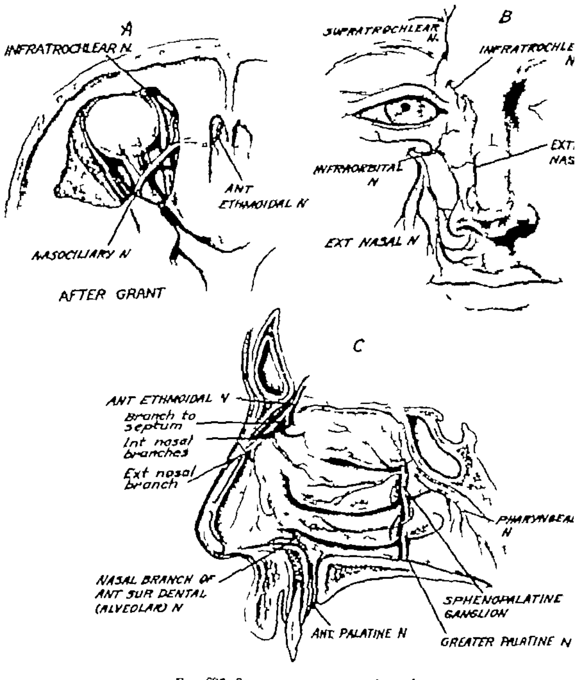


Fig 628. The sensory nerve supply to the nose
A. Diagram illustrating the orbital origin of the anterior ethmoidal nerve.
B. The sensory innervation of the nasal pyramid.
C. The sensory innervation of the dorsum and lateral wall of the nose.

only the lower portion of the septal carti lage.

The approach to the nasal framework va ries with the site of deviation. When the lower edge of the septum is straight, a verti cal incision is made about 1 cm behind the lower margin of the septal cartilage down to the floor of the nose (Fig 629D) To avoid postoperative septal hematoma a h incision is then made along the flo nose which joins the lower anteri the previous vertical incision (Fi These incisions must be placed p to the posterior vestibular fold th the formation of a scar web due to ture which follows the healing c

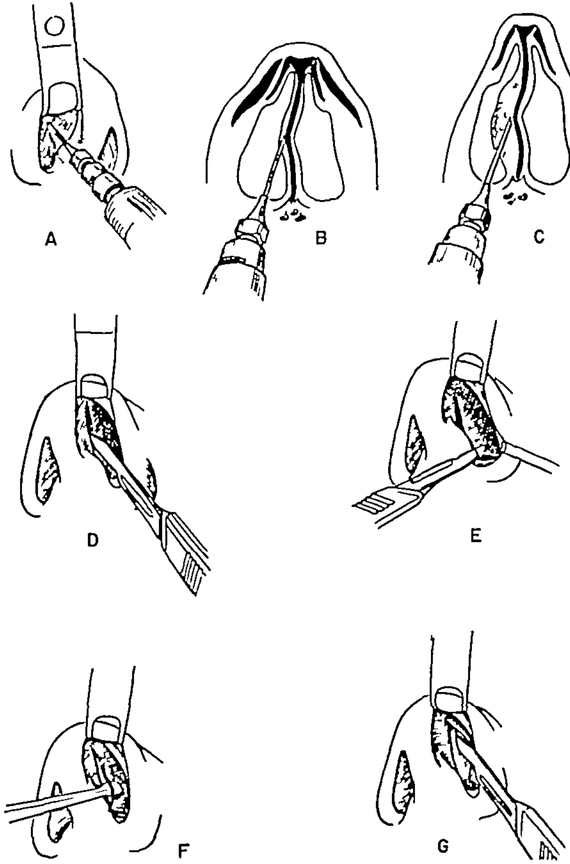


Fig 629 Technique of submucous resection of the deviated septum

A. Infiltration beneath the mucoperichondrium.

B. Cross section illustrating the plane of infiltration between the cartilage and the mucoperichondrium.

C. The mucoperichondrium on the right side is raised by the injected fluid

D After infiltration of the mucoperichondrium on the left side incision for exposure of the septal framework.

E. Horizontal incision along the floor of the nose joining the lower end of the vertical incision

F Raising the mucoperichondrium on the left side

G Cutting through the septal cartilage

(Continued in next figure)

cision in the posterior vestibular fold or in the vestibule anterior to the fold. Such webbing of the posterior vestibular fold may cause postoperative obstruction of the nasal airway When it is necessary to expose the entire septal framework, the exposure of the framework is initiated at the lower margin of the septal cartilage through the transfixion incision. The cartilage is im mobilized with tooth forceps and the mucoperichondrium is sharply dissected beginning at the cartilage the mucoperi chondrium is adherent in this area

The mucoperichondrium is then raised on the left side (Fig 629*F*) After exposing the entire left side of the septal framework, an incision is made through the cartilage to expose the right side (Fig 629G) A ver tical incision is made through the cartilage a few millimeters behind the original in cision in the mucoperichondrium, in order that the mucoperichondrial and cartilagin ous incisions do not coincide The instru ment is passed through the incision and the mucoperichondrium is elevated from the right side of the septal framework (Fig 630*A* *B*) Both mucoperichondrial flaps are then retracted either by septal retractors or a nasal speculum The septal cartilage is cut through in the routine submucous resection leaving a piece of cartilage 1 to 2 cm in height along the dorsal margin to give adequate support to the new dorsal border of the nose. The cartilage is cut through at this level with septal scissors (Fig 630*C* *D*)

In order to evaluate the distance at which this cut is to be made the septal scissors are placed through the incision in the septal cartilage and the blades of the scissors are left open. The index finger of the left hand is then placed along the dorsum and by pal pation of the dorsal edge of the septum and direct inspection of the position of the scis sors inside the nose, it is possible to evaluate the height of the segment of the cartilage remaining along the dorsum When an ade quate level has thus been established the cartilage is cut back toward the perpendicu lar plate. A second horizontal incision is now made with the septal scissors at the junction of the septal cartilage and the vomer posteriorly to the perpendicular plate and a vertical incision is made at the junc tion of the septal cartilage and the perpendicular plate of the ethmoid (Fig 630*E*) The segment of the cartilage is then with drawn (Fig 630*F*) By this method it is possible to obtain a sizeable piece of cartilage for a nasal implant.

After resection of the deviated segment of cartilage removal of the deviated frame work of the septum is completed by fractur ing the perpendicular plate with the Bruen ing forceps and removing the segment from the nasal cavity (Fig 631*B*) Parts of the vomer can also be fractured and re moved with the Bruening forceps or with a heavier instrument such as the McCoy for ceps Another method for removing the vomer particularly the portion along the floor of the nose is to expose the vomer by re traction of the mucoperichondrial flaps and with a narrow osteotome and a mallet, sever the connections of the vomer to the nasal floor and remove it with the aid of the Bruening forceps (Fig 631*C*) The original vertical incision through the mucoperichon drium is then sutured with 4-0 plain catgut. The incision along the floor of the nose pre vents the collection of blood between the flaps.

A submucous resection of the nasal septum is usually a fairly simple procedure. The operation can however be tedious and difficult when one is dealing with a pre viously badly traumatized septum It is an arduous task to elevate the mucoperichon drial flaps from a septum that has been re peatedly traumatized a classical example of the condition is found in the nose of the professional pugilist. Here repeated trauma has caused subperichondrial hemorrhage and the organization of a fibrin mass which has become scar tissue. Careful elevation of the flaps by sharply dissecting the tis sue from the septal framework is required

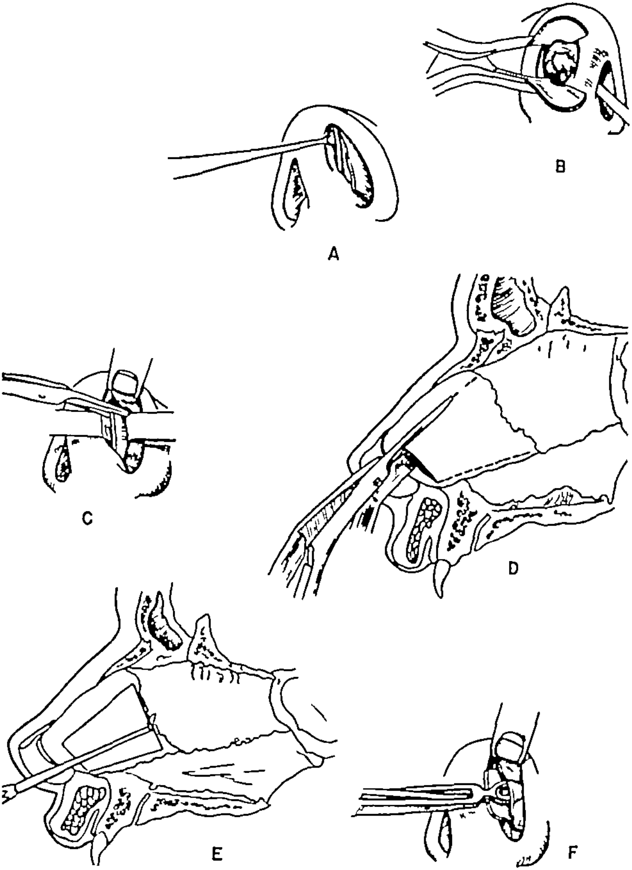


Fig 630. Technique of submucous resection of the deviated septum (*continued*)

A. Raising the mucoperichondrium on the right side

B. The raising of the mucoperichondrium is observed through the speculum placed in the right nasal fossa.

C. Cutting through the septal cartilage with septal scissors.

D. Indicating the level of the horizontal incision leaving a strip of cartilage along the dorsum of the nose

E. Severing the area of junction of the septal cartilage with the perpendicular plate of the ethmoid.

F. Removal of the resected septal cartilage

(*Continued in next figure.*)

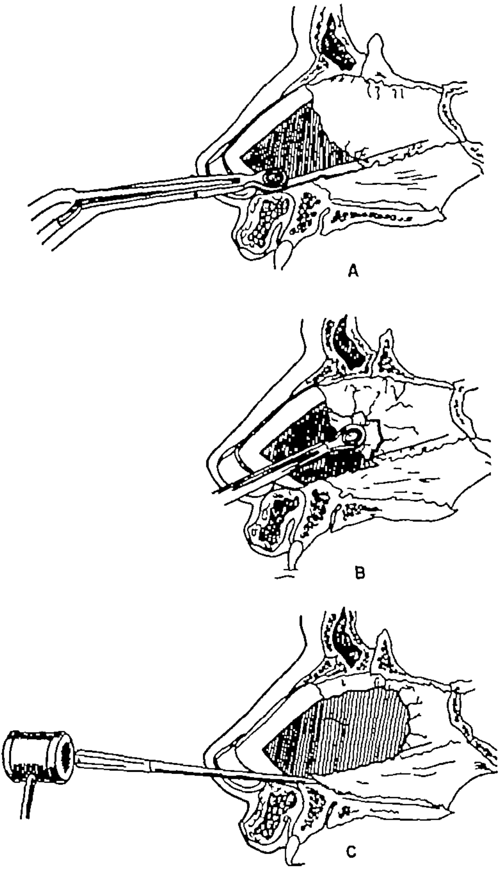


FIG 631 Technique of submucous resection of the deviated septum (*continued*)

A. Removal of the remainder of the septal cartilage with the Bruening forceps.

B. Fracture and removal of the deviated perpendicular plate of the ethmoid.

C. Resection of the vomer with an osteotome.

TABLE 6

Summary of the five successive stages of a routine nasal plastic operation

Stage I	Uncovering of nasal framework
Stage II	Modification of profile line and shortening of septum (The Septal Parenthesis)
Stage III	Osteotomy of lateral walls
Stage IV	Tip Surgery
Stage V	Splinting

to separate them from the septum. In such difficult cases of submucous resection it is necessary to proceed with care in order not to tear the flaps, particularly on both sides and thus produce a perforated septum.

Patience and care are also required in certain badly deviated septa, as in those with marked angulations and spurs. The mucosa has become extremely thin over the convexities of the severe angulations and spurs and the tearing of the flap is inevitable because of this condition. The thinness is usually due to constant pressure from the underlying bony or cartilaginous protuberance; it may also be due to traumatization by the patient who, in efforts to relieve the obstruction, has adopted the habit of picking the nose, thus causing repeated ulcerations over an angulated area which becomes healed by scar tissue formation. The thin scar epithelium is extremely friable and tears easily. The mucoperichondrial flap on the concave side must be preserved; thorough infiltration of the concave side with novocaine-adrenalin assists in the elevation of the flaps.

In some very badly deviated septa, where the angulations meet each other at an almost 90 degree angle, it is advisable to proceed with the resection in a segmental fashion. The lower deviated portion is exposed and that segment of the cartilage is removed, after which the posterior deviated portion is exposed and removed.

The nasal cavities are lightly packed with Vaseline gauze following completion of the submucous resection. Too much reliance cannot be placed upon packing to prevent a septal hematoma because of the possibility of displacing the mobilized lateral walls of the nose. The horizontal incision along the floor of the nose is essential to provide drainage and prevent hematoma.

The Corrective Nasal Plastic Operation

Table 6 summarizes the five successive stages which systematize the procedures required to perform the typical corrective nasal plastic operation. The nasal framework is uncovered in the first stage. The profile line of the nose is modified and the septum shortened in the second stage. Osteotomy of the lateral walls to narrow the nasal pyramid is performed in the third stage. The tip is modified in a fourth stage. The nasal structures are splinted in the fifth or final stage.

Straightening the nasal septum requires an additional step in the corrective nasal plastic operation and should be performed between the second and third stages after the profile is modified and the septum has been shortened. At this time, the overlying nasal structures have been freed from the framework, the remaining septum is clearly defined and straightening the septum may be done previous to the mobilization of the lateral walls, thus avoiding undue injury.

When the patient is on the operating table and has been adequately prepared for surgery, it is helpful to locate various landmarks just before the first incision is made.

Palpation along the dorsum reveals the location of the septal angle. Upward traction on the skin of the dorsum causes blanching of the skin at the domes of the alar cartilages, thus locating these structures (Fig. 632B). An applicator stick placed along the proposed new profile line (Fig. 633) is often a helpful procedure.

The degree of protrusion of the septal angle should be considered in relation to the proposed profile line, for in the humped nose the septal angle may be situated high in relation to the alar cartilages. The following test (the septal angle test) may be

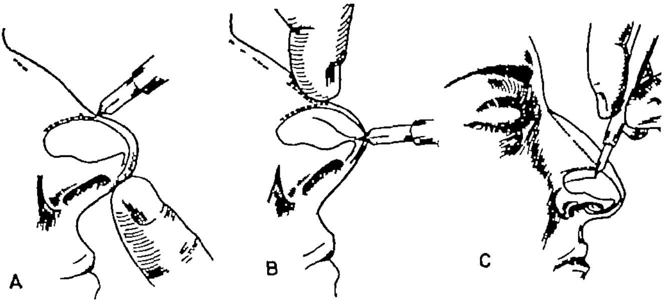


Fig 632. Landmarks for tip surgery
A. Outlining the upper border of the lateral crus.
B. Marking the apex of the dome.
C. Outlining the upper segment of the alar cartilage to be excised.
(Figs. 632 to 635 from J M. Converse, Laryngoscope, 57 16, 1957)

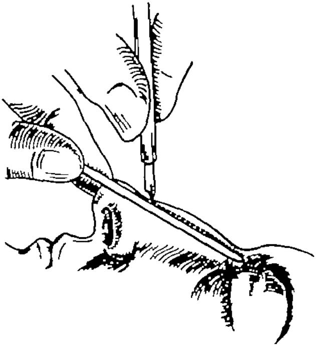


Fig. 633 The applicator stick placed along the new profile line.

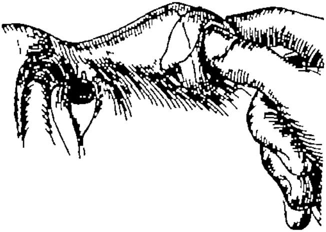


Fig 634 The septal angle test. A useful test to assist the surgeon in evaluating the amount of cartilage to resect from the septal angle. Traction downward upon the columella causes the septal angle to protrude under the skin of the supratip area if cartilage remains in excess in this area.

employed to assist in visualizing the septal angle. The thumb and index finger are placed along both sides of the columella exerting a downward traction upon it, drawing the tip downward and causing the septal angle to protrude (Fig 631)

Overshortening of the nose is disastrous, and undershortening may fail to correct the obvious deformity An excellent method to determine the required amount of shortening is described by Aufricht (1943)

The index finger is placed on the side of the dorsum the tip of the finger resting on the root of the nose (Fig 635*A*) The proposed profile can thus be visualized and indicated by an ink line along the radial margin of the gloved finger which covers the

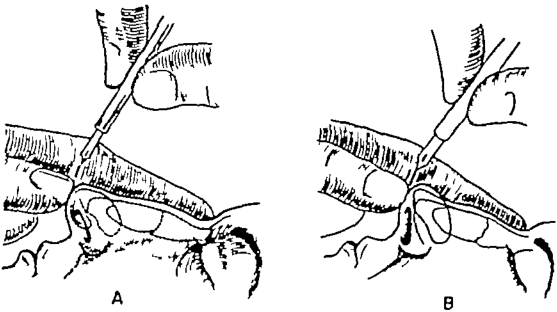


FIG 635. The finger test to determine the amount of required shortening of the nose (after Aufricht, 1943)

A. The index finger is placed on the side of the dorsum, the tip of the finger resting on the root of the nose. The thumb is placed at the tip and indicates the actual length of the nose

B. The tip of the nose is raised by thumb pressure until the desired shortening is visualized. The distance between the ink marks represents the base of the triangle to be excised from the anterior-inferior portion of the septal cartilage

objectionable hump Retaining the index finger in this position the tip of the nose is raised by thumb pressure until the desired shortening is visualized the location is then fixed by an ink dot on the gloved index finger (Fig 635*B*) Thumb pressure on the tip is then released the nose resuming its normal length A second dot of ink on the gloved finger marks this point. The distance between the ink marks represents the base of the triangle to be excised from the antero-inferior portion of the septal cartilage.

Surface landmarks are also employed on the skin of the nose Small lines at the lower border of the nasal bones and at the upper margins of the alar cartilages are drawn on the skin with ink to define these structures (Fig 632*A*) An ink line divides the lateral crus into an upper and lower field (Fig 632*C*) the upper field includes the undesirable convexity of the tip and is of variable width Ink diagrams are of aid in memorizing the dimensions during the operation

The size and shape of the columella its degree of protrusion in relation to the base of the alae the angle at which it meets the lip or *nasolabial angle* and *the nasofrontal* angle are noted. If narrowing the base of the ala is required the amount to be excised may be outlined in ink abnormalities or deviations of the septum should also be defined

Stage I Uncovering the Nasal Framework

Topical anesthesia precedes infiltration anesthesia Cotton tipped copper wire applicators are dipped in a solution consisting of equal parts of 10 per cent cocaine and 1 1000 adrenalin the excess is removed in order to prevent the solution from entering the nasopharynx and pharynx One applicator is extended *through the nasal passage* to the root of the nose where the anterior ethmoidal nerve enters the nasal cavity (Fig 636) The other applicator is passed posteriorly to the mucosa over the sphenopalatine ganglion thus applying the anesthetic to the nerve branches from the ganglion the applicators are retained in position for a few minutes.

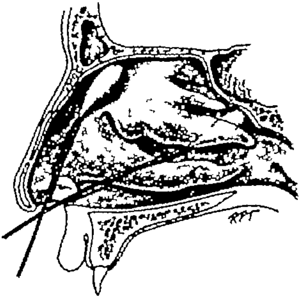


FIG 636. Topical anesthesia of the nose. Cotton tipped applicators dipped in anesthetic solution are placed over the anterior ethmoidal nerve and sphenopalatine ganglion.

Topical application is followed by infiltration anesthesia with procaine and adrenalin. The internal naris is visualized by retracting the ala the solution is then introduced into the tissues immediately above the lower border of the lateral cartilage, directed toward the root of the nose (Fig 637*A*) The plane of infiltration should follow the outer surface of the cartilage and bone Another injection is made at the junction of the lateral cartilage and septum (Fig 637*B*) A third injection is made in the region of the septal angle (Fig 637*C*) Additional solution is then injected between the layers of the membraneous septum to block the nasopalatine nerve (Fig 637*D*) The left ala is then retracted and an injection similar to the first one on the right side is made by placing the needle over the lateral cartilage and infiltrating toward the root of the nose. Additional injections on the left side are unnecessary for the injections on the right side have already infiltrated the areas.

An incision is made at the lower border of the lateral cartilage (Fig 638*A* *B*) This is designated as the intercartilaginous incision because it is placed between the alar and lateral cartilages The length of the incision which should always extend to the mid line varies with the size of the hump to be removed and also depends upon the amount of alar cartilage to be freed during the tip surgery A double bladed Joseph knife is used to sharply dissect the soft tissues from the lateral cartilage, extending the dissection to the mid line (Fig 638*C*) The plane of dissection should be subperichondrial thus preventing injury to the overlying musculature of the nose little bleeding occurs, for the blood vessels of the nose are superficial. The handle of the knife should be maintained along a plane parallel with that of the dorsum of the nose to avoid buttonholing the skin with the tip of the instrument. The dissection is extended

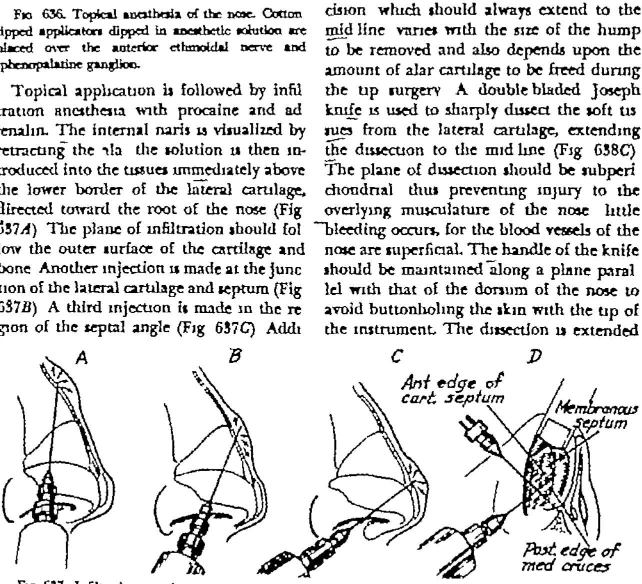
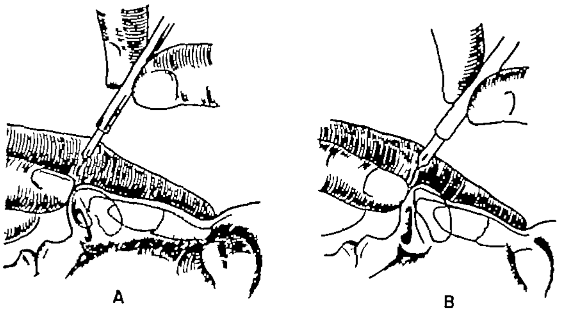


FIG 637 Infiltration anesthesia for the first stage. Illustrates injections at the root of the nose (A) at the junction of the septum and lateral cartilage (B) at the septal angle (C) and in the membranous septum (D)

(Figs. 637 to 647 from J M. Converse in C. Jackson and C. L. Jackson, *Diseases of the Nose Throat and Ear* Ed. 2, W B. Saunders Co., 1939)



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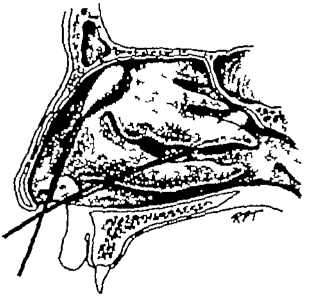

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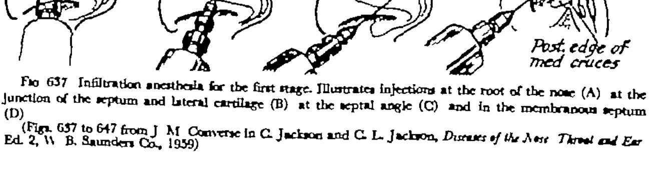

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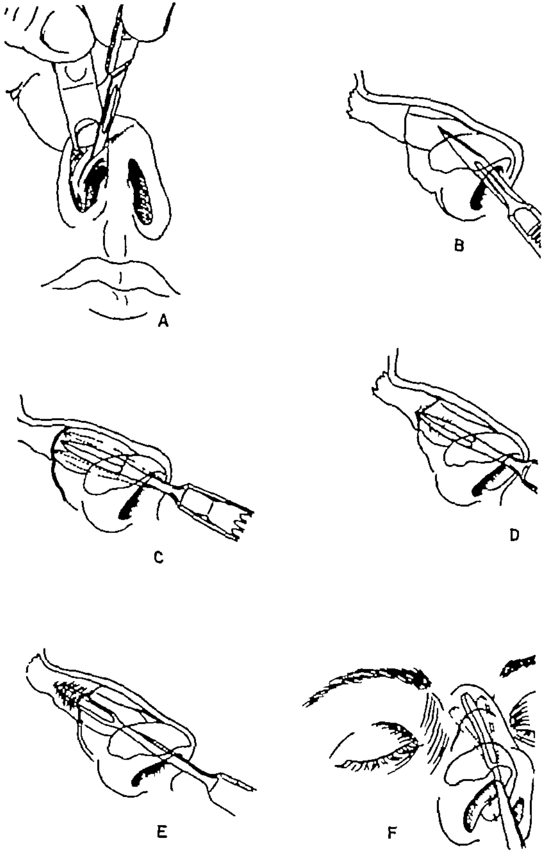

Fig. 638. Corrective nasal operation First stage

A and B Intercartilaginous incision.

C. Sharp dissection over the lateral cartilage with the Joseph knife.

D Incision in the periosteum with the tip of the Joseph knife.

E. Elevation of the periosteum

F The elevation of the periosteum over the nasal bone is extended to the mid-line

over the lateral cartilage to the lower border of the nasal bones An incision is then made in the periosteum (Fig 638D) a periosteal elevator is placed through the incision (Fig 638E) and the periosteum is elevated to the mid line (Fig 638F) Similar procedures are repeated on the left side.

Subperiosteal elevation over the nasal bones is routine less bleeding occurring than above the periosteal level In instances of an unusually large hump it is preferable to remove the periosteum with the bone, for excess periosteum remaining after a reduction in the size of the nose may cause a thickening over the dorsum. In such cases the periosteum is left attached to the nasal bones and the dorsal hump is removed with the periosteum

The next procedure is known as the transfixion a technique in which the soft tissues overlying the dorsum are separated from the septum A button knife is introduced through the incision made at the right internal naris into the subperiosteal pocket over the nasal bones. An incision is then made along the dorsal border of the

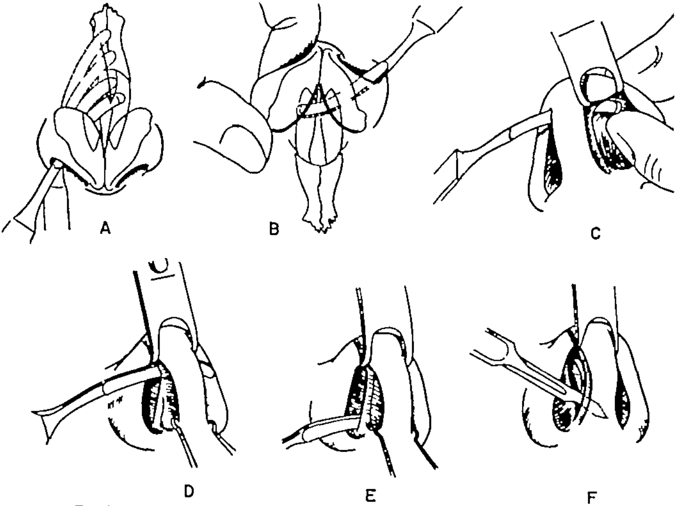

Fig 639 Corrective nasal operation First stage (*continued*)—the transfixion procedure

A. A button knife is introduced through the right intercartilaginous incision, then extends downward along the dorsal border of the septum.

B. When the tip of the button knife reaches the intercartilaginous incision on the left side it is extended into the left vestibule.

C. Demonstrates the tip of the button knife extended into the left vestibule through the *left intercartilaginous incision.*

D Illustrates upward traction of the tip and forward traction of the columella by means of hooks placed along the posterior border of the medial crura, thus tensing the membranous septum.

E. Incision along the lower border of the septal cartilage.

F The incision is extended down to the nasal spine, if exposure of this area is required

septum until the tip of the knife reaches the incision at the internal naris of the opposite side (Fig 639A) The tip of the button knife which may be palpated as it reaches the incision at the left internal naris, is extended into the left vestibule and the incision is continued to the septal angle (Fig 639B C) The membranous septum is tensed by a downward and forward pull on the columella employing a hook on each side of the posterior margin of the medial crura and the tip of the nose is retracted upward (Fig 639D) The button knife is then rotated about 90 degrees, cutting downward along the free margin of the septal cartilage toward its base (Fig 639E) Forward traction upon the columella assures its attachment to the membranous septum in subsequent shortening procedures upon the septal cartilage the membranous septum is not removed. A No 15 blade is employed if further surgery upon the nasal spine and the base of the septal cartilage is required (Fig 639F) Extensive undermining procedures in the region of the nasal spine and lip are unnecessary Such procedures increase the tendency for downward contraction during healing

The transfixion procedure completes the uncovering of the nasal framework. The periosteal elevator is passed through the plane of dissection to verify the completion of the uncovering procedure and also to determine that no adhesions remain between the overlying soft tissues and the nasal framework. Remaining bands of tissue are sectioned

Stage II Modification of the Profile and Shortening of the Septum

Modification of the nasal profile usually requires the excision of an osteocartilaginous hump accomplished routinely with a bayonet saw The tip of the index finger is placed in the bend of the bayonet, and operating on the right side of the patient a back handed technique is used to resect the hump (Fig 640A) The bayonet portion of the saw is directed upward a position which permits better surveillance. The saw is introduced into the undermined area and placed along the right side of the upper portion of the dorsum of the nose at the predetermined level The hump is usually completely loosened by this one-sided sawing, but additional use of the saw on the left side may be required to complete the section (Fig 640B) Only the lower portion of the hump now remains attached, and the hump can usually be lifted through the skin although it is still attached at the level of the lateral cartilages and the cartilaginous septum To separate the hump from these attachments the button knife is placed beneath it and is extended downward, severing the remaining connections to the lateral and septal cartilages (Fig 640C) the hump is then removed with a forceps (Fig 640D). The profile line is modified by the excision of the hump and the cut surfaces of the bones and cartilages are inspected irregularities along the line of osteotomy are smoothed with a rasp (Fig 640E)

A curette like instrument known as a sweeper" is employed to remove debris and bone dust. Irregularities along the dorsal border particularly the septal cartilage are shaved with the button knife or angulated scissors The septal angle test is employed to determine that an adequate level has been attained (see Fig 631)

Remaining attachments of the lateral cartilages to the septum are severed (Fig 641A B) A piece of cartilage from the lower margin of the septal cartilage is removed when the nose requires shortening (Fig 641C), using the measurements obtained by the finger test (see Fig 635)

Small angulated retractors held by the assistant are employed to expose the septal angle The cartilage is steadied by grasping it with a tooth forceps, and a suitable amount is excised (Fig 641C) It is preferable to remove this triangular piece with a knife for the lower margin of the septal

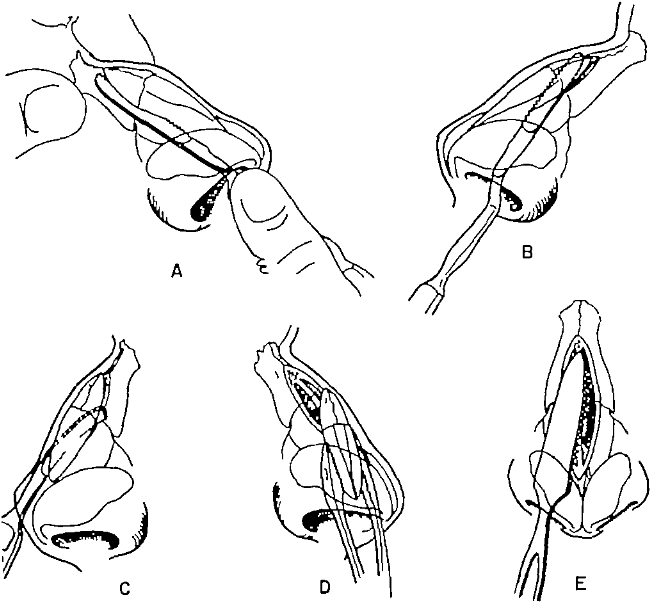

FIG 640 Corrective nasal operation Second stage—resection of hump

A. The bayonet saw is placed on the right side of the hump and resection is accomplished by backhanded technique.

B. Completion of the hump resection from the left side.

C. The button knife is placed beneath the hump and severs the remaining connections to the lateral and septal cartilages.

D The hump is removed with the hump removal forceps.

E. Irregularities along the line of osteotomy if present, are smoothed with a rasp.

cartilage follows the slight curve of the columella. The free margin of the septal cartilage should be given this type of curve and fitted to the columella. Excess septal cartilage should be removed for it results in a wide nasolabial angle, which is usually due to the protrusion of the lower margin of the septal cartilage into the lip. The nasal spine may also require trimming

The septal angle is rounded, and a small area of cartilage is exposed by removing the mucoperichondrium for a distance of approximately 2 to 3 mm. (Fig 641*D*) This precautionary procedure is necessary for the overlapping mucoperichondrium may prevent close coaptation of the septal angle with the overlying structures, causing a rounded appearance of the supratip area.

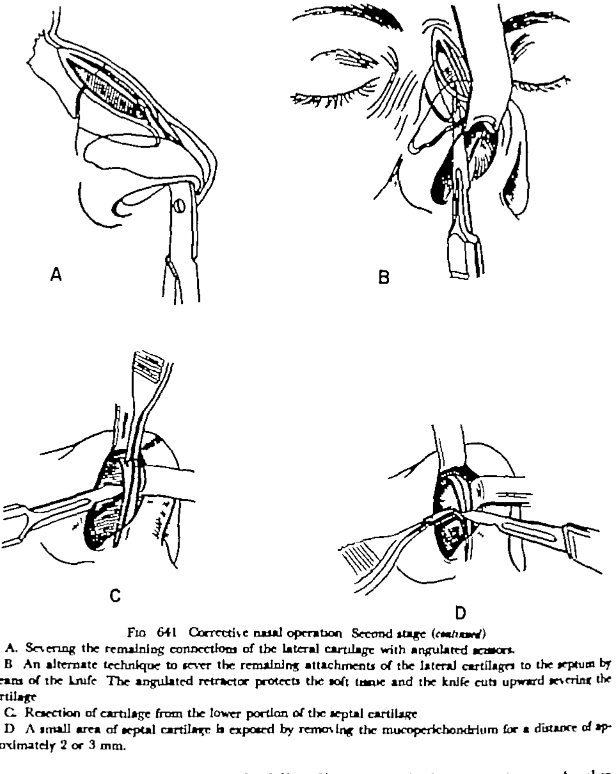

Fig 641 Corrective nasal operation Second stage (*continued*)

A. Severing the remaining connections of the lateral cartilage with angulated scissors.

B An alternate technique to sever the remaining attachments of the lateral cartilages to the septum by means of the knife The angulated retractor protects the soft tissue and the knife cuts upward severing the cartilage

C. Resection of cartilage from the lower portion of the septal cartilage

D A small area of septal cartilage is exposed by removing the mucoperichondrium for a distance of approximately 2 or 3 mm.

Stage III Osteotomy of the Lateral Walls of the Nose

Additional anesthesia is required for osteotomy of the lateral nasal walls. An injection into the right vestibule which extends through the skin of the vestibule and the base of the ala into the region of the nasolabial fold (Fig 612*A*) blocks the terminal filaments of the infraorbital nerve Another injection toward the lip blocks lower nerve filaments which enter the vestibule from the lip Still another injection is made immediately in front of the inferior turbinate to block nasal branches of the anterior superior alveolar nerve (Fig 612*C* see also Fig 628)

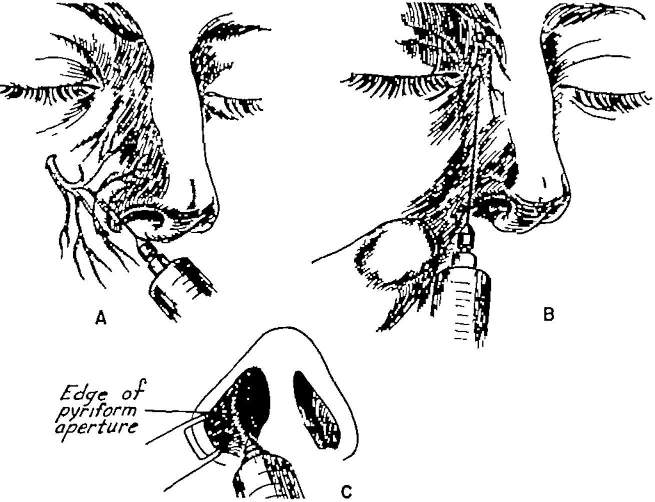

FIG 642. Local anesthesia for the third stage

A. An injection is made in the right vestibule through the base of the ala into the region of the nasolabial fold blocking filaments from the infraorbital nerve.

B. The base of the right ala is retracted outward and a long needle is introduced along the base of the lateral wall of the nose.

C. Injection made immediately in front of the anterior tip of the inferior turbinate to block nasal branches of the anterosuperior alveolar nerve (see Fig 628*C*)

The right ala is retracted outward and a longer needle, (5 cm.) is introduced into the vestibule, lateral to the border of the pyriform aperture this is passed upward following the contour of the bone to a point anterior to the medial palpebral ligament (Fig 642*B*) the solution is injected as the needle is withdrawn

The border of the pyriform aperture is located with the handle of a Joseph knife, using the instrument to palpate the edge of the aperture (Fig 643*A*) A stab incision through the soft tissues and the periosteum is established lateral to the border of the pyriform aperture (Fig 643*B* *C*) A periosteal elevator is then placed subperiosteally through this incision (Fig 643*D*) The elevator is slightly rotated upon itself as it passes upward along the base of the lateral wall of the nose to a point just anterior to the medial palpebral ligament, creating a subperiosteal tunnel large enough to introduce a saw blade. A Joseph's saw guide facilitates the passage of the saw the tip of the guide is directed against the bone and traction exerted in a downward and slightly lateral direction the stab incision is thus opened (Fig 643*E*) The osteotomy can be initiated by the use of a right handed angulated saw The introduction of the saw into the subperiosteal tunnel should be performed with finger-tip delicacy The instru

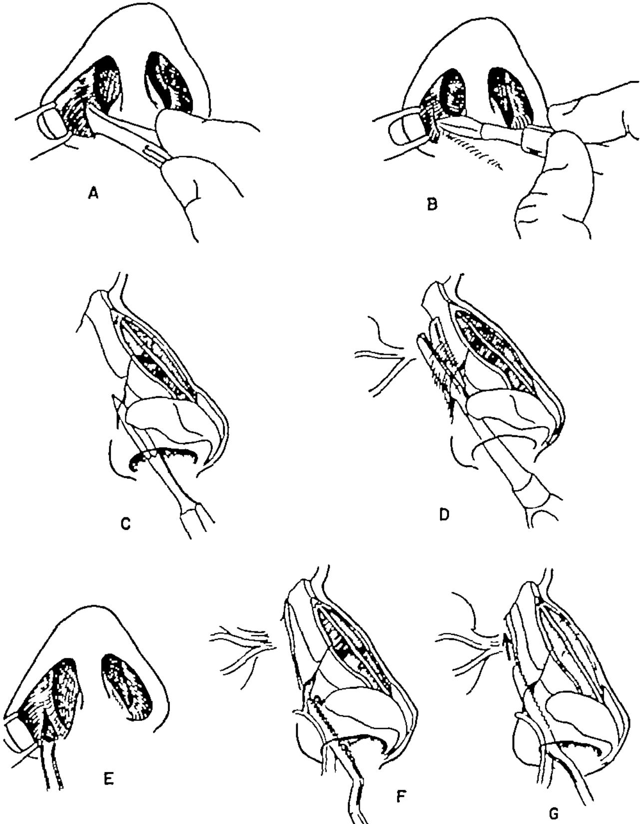

Fig 643. Corrective nasal operation Third stage—Osteotomy of the lateral nasal walls

A. The border of the pyriform aperture is located with the handle end of the Joseph knife.

B A stab incision is made through the soft tissues and periosteum.

C. Illustrating the stab incision extending through the periosteum lateral to the border of the pyriform aperture

D Introduction of a subperiosteal elevator creating a subperiosteal tunnel extending along the base of the lateral wall of the nose to a point just anterior to the medial palpebral ligament.

E. Joseph saw guide in position opening the stab incision.

F The saw is rotated into position. The teeth of the saw should be placed against the bone in order to avoid injury of the soft tissues.

ment is held as a pen and slowly rotated into the tunnel Friction of the saw teeth against the Joseph guide causes the blunting of the instrument the teeth of the saw should be applied against the bone to avoid soft tissue injury

The saw should be directed straight across the base of the lateral wall in order to cut through it (Fig 644) The base of the lateral wall presents its maximum thickness at the junction with the body of the maxilla. If the saw is directed obliquely inward, and backward a much greater thickness of bone must be traversed, thus rendering the procedure more laborious To facilitate the procedure, the patient's head is turned as far over to the side as possible and immobilized by the assistant. Only a slight amount of pressure should be exerted upon the saw in order to avoid a jamming between the edges of the groove. The sawing is continued until completed to avoid removing the instrument from its bony groove and establishing a second groove at the side of the first. The operator will be aware of a slight "give when the saw penetrates the periosteum on the inner surface of the bone A few remaining lightly applied strokes complete the separation.

The lateral walls of the nose form the sides of a pyramid and are directed obliquely downward, not vertically diverging at the lower portion. The saw must be applied obliquely in order to be parallel to the lateral walls. Failure to place the saw correctly may result in sectioning the lower part of the lateral wall before the upper

The line of osteotomy is cleansed of bone dust with the "sweeper (Fig 645*A*) Each remaining minute particle of bone is potentially osteogenetic, and such fragments can result in thickening along the base of the lateral wall

Similar procedures are then undertaken on the left side anesthesia of the lateral wall being obtained in the manner previously described.

The quality of the result obtained in na

Fig 644 Illustrating the position of the angulated saw at the base of the lateral nasal wall.

sal plastic surgery depends upon adequate mobilization of the walls in order to obtain satisfactory narrowing of the nasal dorsum Inward mobilization may be attempted by thumb pressure infracturing the lateral nasal wall toward the mid-sagittal line Two complications may occur as a result of this procedure (1) splintering the bony lateral nasal wall and (2) inadequate narrowing of the upper portion of the bony dorsum

1 SPLINTERING THE BONY LATERAL NASAL WALL. The lateral wall of the nose, instead of being disarticulated in one piece at its junction with the frontal bone may break somewhere at its middle third a sharp spicule may remain firmly attached to the root of the nose and the bony wall may be broken in a number of places. Even after the bony sides are completely severed from their frontal attachments and mobilized inward the dorsum of the nose may still remain wide particularly in the upper portion.

2. INADEQUATE NARROWING OF THE UPPER PORTION OF THE BONY DORSUM Resection of an average sized hump involves the lower thin part of the nasal bones and the adjacent lateral cartilages and septum but does not include the thick upper portion of the

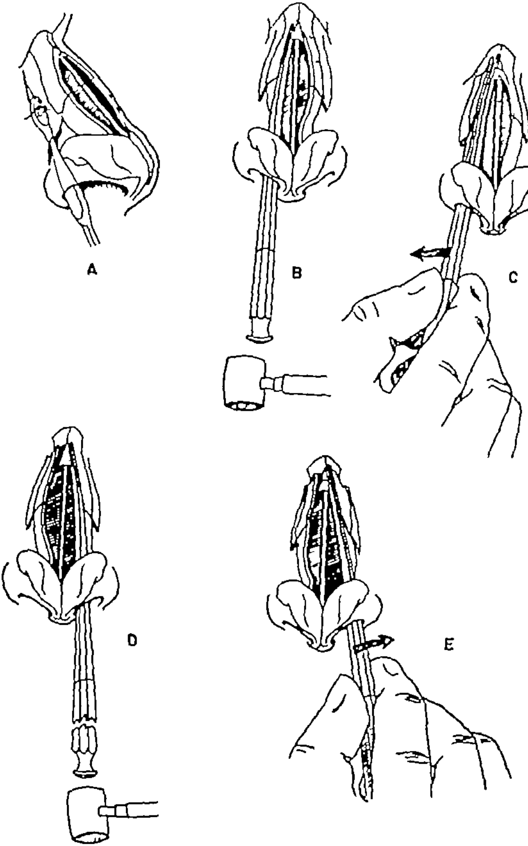

FIG 645 Corrective nasal operation Third stage (*continued*)—the out fracture procedure

A Area of lateral osteotomy is cleansed with the "sweeper"

B A line of section is established through the bone web

C The osteotome levered outward and slowly rotated causes a fracture of the remaining bony attachment of the lateral nasal wall

D Line of section established by means of the osteotome through the bony web on the left side

E Out-fracture of the left lateral nasal wall

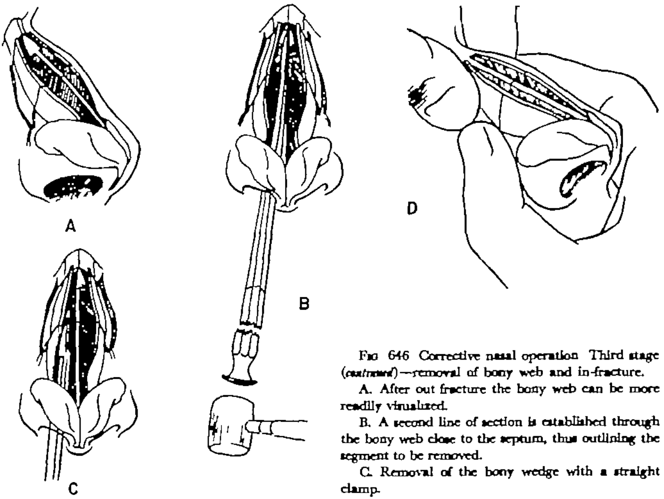

Fig 646 Corrective nasal operation Third stage (*continued*)—removal of bony web and in-fracture.

A. After out fracture the bony web can be more readily visualized.

B. A second line of section is established through the bony web close to the septum, thus outlining the segment to be removed.

C. Removal of the bony wedge with a straight clamp.

bones. A weakened area is produced due to the removal of the hump the thick upper portion however remains intact. A bony web at the upper portion of the dorsum is an obstacle to adequate infracturing of the lateral walls, and must be removed.

Out fracture of the lateral bony wall of the nose is advisable prior to the removal of this intervening portion. The purpose of out fracturing is 3-fold (a) to sever the remaining connection of the lateral nasal wall with the frontal bone, (b) to insure adequate loosening at the line of osteotomy and (c) to establish sufficient space for the insertion of an instrument to remove the bony web

An osteotome is placed in the space between the cut edge of the nasal bone and the septum to out fracture the lateral wall A line of section upward through the remaining bone is established by the use of mallet and osteotome (Fig 645*B*) A characteristic dull sound is heard when the osteotome penetrates the dense bone at the root of the nose. The osteotome levered outward from the frontal bone is slowly rotated the remaining attachment of the nasal bone and the frontal process is fractured close to the frontal bone attachment, the entire bony lateral wall is then out fractured (Fig 645*C D E*)

An osteotome with a guard is employed for this procedure to protect the overlying soft tissues and skin from trauma and also to permit palpation of the tip of the instrument through the skin. The use of a curved osteotome may be preferable in the large nose in order to follow the curve of the cut surface of the nasal bone.

After out fracturing, retraction permits direct examination of the area and reveals the wedge of bone to be removed (Fig 646*A*) a second line of section, medial to the first outlines the segment (Fig 646*B*) and the wedge of bone is removed with a straight clamp (Fig 646*C*). Similar proce

A B C D

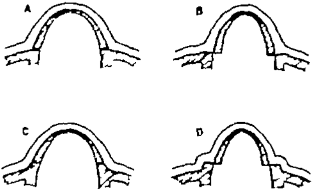

Fig 647 Importance of sectioning the lateral nasal wall at its base.

A and B Correct level at which the osteotomy should be performed.

C and D If the osteotomy line is not at the base of the lateral nasal wall, a step-like protuberance results.

dures are undertaken on the left side. The lateral wall may then be placed in closer apposition to the septum throughout its entire length by light finger pressure (Fig 616D) The intervening bony wedge may also be removed with the aid of a special rongeur the nasal forceps. The rhinoscope a retractor with a light bulb similar to a small laryngoscope is a useful instrument for direct visualization of the area

Other minor obstacles must be removed to achieve adequate narrowing of the dorsum these are eliminated after careful inspection Excess mucosa on both sides of the septum is trimmed at the edges of the cut surface of the transfixion incision it may also be necessary to trim excess mucoperiosteum along the edge of the nasal bones following hump resection in order that soft tissues do not interpose or interfere with the narrowing procedure Sawdust and debris between the nasal fragments are removed with a curette. A high deviation of the septum which may interfere with medial displacement of the lateral walls must also be corrected this is one of the most frequent causes of inadequate narrowing of the bony nasal bridge following rhinoplasty The dorsal border of the septum occasionally shows an excessive projection in relation to the external nasal walls and must be removed.

The osteotomy line should be palpated to determine whether any stepping of the area exists this complication may result when the saw has been placed at too high a level rather than at the base of the frontal process, where it rises from the body of the maxilla (Fig 617A B). If the saw is placed above this level or if it slips upward, a ridge lateral to the osteotomy line may result in a step-like protuberance at the base of the lateral wall (Fig 617C D). If such a complication occurs, the crest remaining at the base of the lateral wall should be fractured inwardly using a narrow and fine tipped osteotome placed through the skin. Palpation along the dorsum of the nose may reveal irregularities overlapping of bone is smoothed with a rasp

Stage IV Tip Surgery

It is generally agreed among surgeons engaged in nasal plastic surgery that satisfactory surgery of the tip of the nose offers difficult and intricate problems of corrective surgery

Following modification of the profile by excision of the dorsal hump the tip area formed by the alar cartilages, remains unaffected (Fig 648A) It is necessary to modify the shape of the nasal tip in order to align it with the remainder of the modified dorsal profile line If surgery is not performed on the alar cartilages and the columella is sutured to the lower margin of the septal cartilage the convexity in the supratip area is increased resulting in the typical "parrot beak profile the slight overlap of alar and lateral cartilages becomes accentuated when the tip of the nose is moved upward (Fig 618B) A disappointing condition results if the alar cartilage is permitted to remain in such a position with the expectancy that the nose will remain shortened. The skin lined alar cartilages do not adhere to the underlying lateral cartilages. The natural spring of the medial crura eventually results in a downward pull on the tip of the nose causing a postoperative

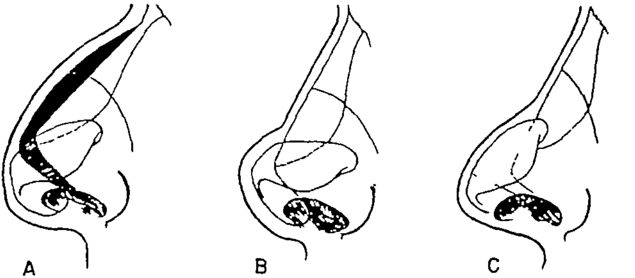

FIG 648. Illustrating the necessity of breaking the continuity of the alar cartilage in the average nasal plastic operation.

A. The shaded area represents the amount of septal framework excised to correct the shape of the dorsum.

B. Position assumed by the alar cartilages after their approximation to the septal angle.

C. If the continuity of the alar cartilage is not interrupted, the elasticity of the cartilage pulls the tip into the position illustrated.

(Figs. 648 to 675 from J M. Converse, Laryngoscope, 57 16 1957)

droop of the tip (Fig 648C) The downward displacement of the tip and the upward displacement of the lateral crura may result in a separation between the septal angle and the supratip area (Fig 649A) The septal mucosa joins the vestibular skin on the undersurface of the alar cartilage on each side (Fig 649B) the pocket thus formed between the septal angle and supra tip area causing a characteristic convexity in the area above the tip (Fig 649C)

Three procedures are required to prevent such complications (1) The alar cartilage must be severed near the junction of the medial and lateral crura to interrupt the continuity of the cartilage and to break its spring like action this permits the lateral crus to "lie down" and align itself with the

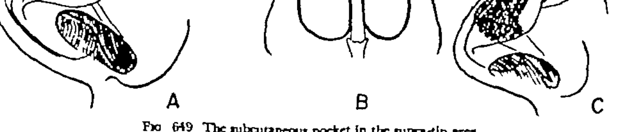

FIG 649 The subcutaneous pocket in the supra-tip area

A. Relationship of alar cartilage and septal angle in deformity shown in Figure 648C.

B. Frontal section demonstrating the pocket formed between the alar cartilages and the septal angle.

C. The shaded area represents the space between the septal angle and the overlying alar cartilages and skin.

new dorsal profile line. (2) Shortening the septum alone does not suffice when the length of the nose is to be reduced the paired lateral walls must also be shortened by excising a portion of each alar cartilage. This is preferable to resecting large portions of the lateral cartilages, for narrowing the internal naris and constriction of the nasal airway may ensue (3) The alar cartilages should be closely adapted to the septal angle to avoid the formation of a pocket between the cartilaginous structures.

Techniques to Expose the Alar Cartilages

Modified Joseph Technique

In the preliminary planning, the lateral crus is divided into an upper and a lower segment, indicated by an ink line drawn upon the skin (see Fig 632) the cartilage in the upper segment represents the excess to be removed.

Because block anesthesia of the area has already been attained in the course of the operative procedures infiltration of the tip is unnecessary The external nasal nerve has been blocked by means of infiltration along the dorsum of the nose branches of the infraorbital nerve have been anesthetized by injections at the base of the alae and filaments of the nasopalatine nerve have been blocked by injection into the membraneous septum Block anesthesia avoids distortion of the tip due to direct injection

The ala of the nose is retracted and two *incisions* are made with a small blade (1) One incision is made along the free margin of the alar cartilage at the dome (Fig 650*A*) this incision is short but should be lengthened if exposure of the lateral crus is planned (2) A cartilage-splitting incision through the vestibular skin and the lateral crus, along a line corresponding to the ink line on the skin delineates the limits between the upper and lower segments (Figs. 650*B* *C*)

A number of methods can be employed to evaluate the width of the upper segment. A fine needle may be inserted through the ala at the predetermined level (Fig 637) the point of *perforation* of the vestibular skin indicates the intranasal line of incision Another method consists of determining the relative size of the upper and lower segments on the outer surface of the nose The free margin of the lateral crus of the alar cartilage is located near the border of the ala the upper margin of the lateral crus is marked, and the upper segment outlined by an additional line placed at a suitable level the proportion in size between the upper and lower segments is then determined. These dimensions are relative because of the thickness of the skin overlying the cartilage the upper segment, for example, may represent one third of the dimension of the lateral crus The upper border of the lateral crus has been exposed by the intercartilaginous incision the lower border of the lateral crus is outlined by the incision at the free margin A third of the distance between these two incisions, beginning at the upper border of the cartilage indicates the site of the cartilage splitting incision

The segments of cartilage resected from the lateral crus are smaller than the areas outlined on the skin The thickness of the skin and soft tissues extending over the alar cartilages accounts for dimensional differences. The cartilage-splitting incision should follow the curve of the upper border of the lateral crus and extend to the medial crus.

A small triangular-shaped piece of cartilage is excised from the region of the dome in the lower segment before resecting the upper segment of the lateral crus. Two transverse incisions through the vestibular skin and cartilage delimit this triangle (Fig 650 *A* to *F*) and the segment with its apex at the free margin of the cartilage is removed with the attached vestibular skin. The excised tissue interrupts the continuity of the medial and lateral crura (Figs. 650*F* and 651*L*) and also serves as an approach

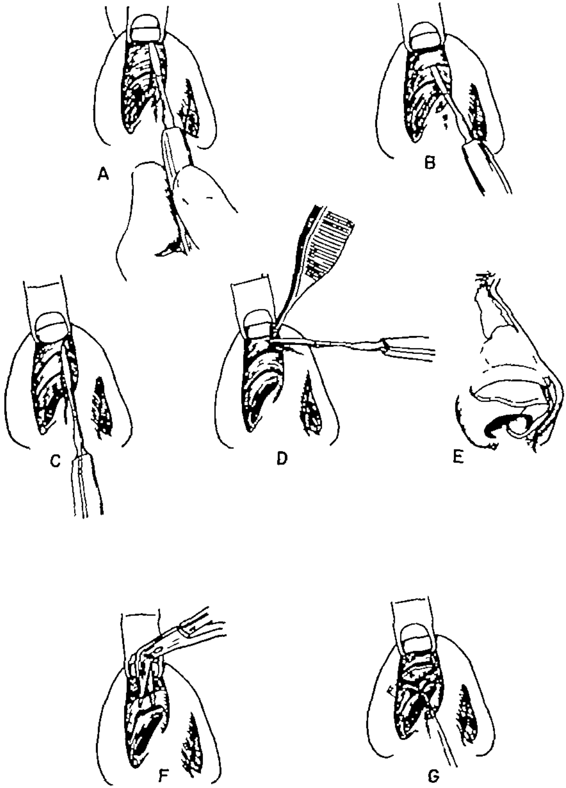

Fig 650. The modified Joseph tip operation

A. The incision along the free margin of the alar cartilage.
B. The cartilage-splitting incision.
C. Incisions outlining a small triangle at the dome.
D Excising the triangle.
E. Appearance of alar cartilage after excision of triangle.
F Subperichondrial separation of the vestibular lining from the upper cartilaginous segment.
G The upper segment is exposed by retraction of the vestibular lining

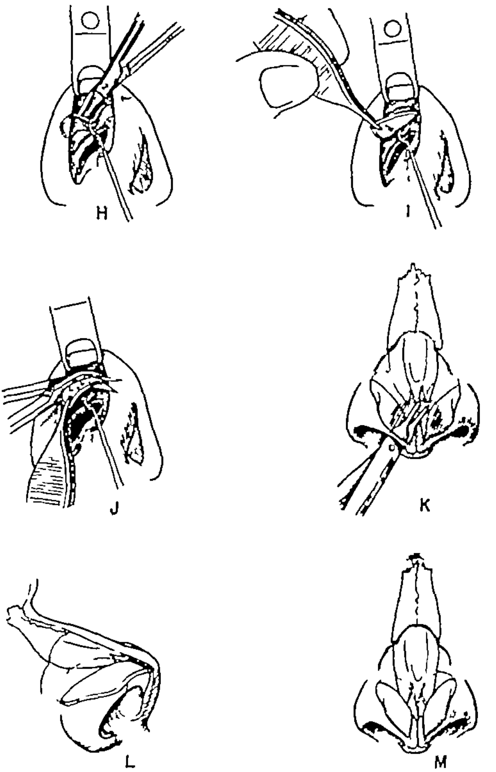

Fig. 651 The modified Joseph tip operation (*continued*)

H Subperichondrial separation of the tissues covering the upper cartilaginous segment.
I Seized with fine tooth forceps the lateral end of the upper cartilaginous segment is extruded.
J The upper cartilaginous segment is cut at its junction with the medial crus
K Subperichondrial raising of the soft tissues over the tip.
L The lateral crus has been mobilized and approximated to the medial crus.
M Frontal view of the cartilaginous structures of the nose at the completion of the operation

for additional removal of cartilage from the lower segment if required

The next step is the excision of cartilage from the upper segment. The vestibular skin is raised from the cartilage with sharp-pointed angulated scissors (Fig 640F) It is advisable to raise the vestibular skin before separating the cartilage from the covering tissues for the cartilage becomes mobile after separation The vestibular skin is retracted by a hook after being separated from the cartilage (Fig 650G) the assistant controls the retractor and hook thus freeing the operator The vestibular skin lining the upper segment of the alar cartilage is completely freed by means of a tooth forceps in one hand and angulated scissors in the other The soft tissues over the cartilage are raised subperichondrially with the scissors (Fig 651H) and the free segment of cartilage is severed near its lateral end. The lateral portion of the cartilage is also included if necessary it is held with the forceps and brought into view (Fig 651I) completely freed medially severed at the junction between the lateral and medial crura and then removed (Fig 651J). Similar procedures are completed on the other side of the nose.

The remaining portion of the lateral crus is freed from the covering soft tissues and the soft tissues over the medial portions of the domes are elevated subperichondrially with small round tip scissors (Fig 651K)

A 3-0 plain catgut mattress suture is then placed to join the medial crura and septal angle and the tip is fitted into the shortened and remodeled nose. A second suture joins the columella to the lower border of the septal cartilage An adequate amount of cartilage must be removed from the area of the lateral crus posteriorly and laterally to the excised cartilaginous segment. Additional removal of cartilage may be required if bulging is noted along the dorsum Sharp angles at the cut edges of the cartilage are smoothed The mobilized structures of the tip ready for manipulation are placed in a suitable position (Fig 651L, M) and retained by adhesive tape around and over the tip of the nose

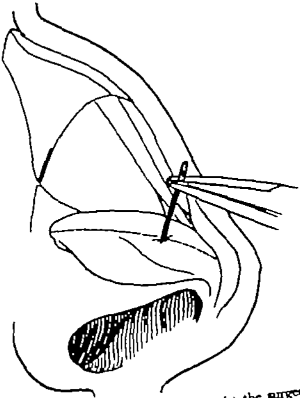

Fig 652. Useful method to assist the surgeon in placing the cartilage-splitting incision at the correct level. A fine needle is introduced through the skin and cartilage. The point at which it pierces the vestibular lining indicates the position of the cartilage-splitting incision.

The Safian Technique

Safian's technique (1935) is a departure from the Joseph operation The initial incision extends along the free margin of the alar cartilage from an area immediately medial to the dome, along most of the length of the lateral crus to the alar cartilage (Fig 653A B) Another incision extended from the medial end of the first incision passes transversely across the alar cartilage joining with the medial end of the intercartilaginous incision (Fig 653C) which extends medially to the dorsal border of the septal cartilage and includes the medial portion of the dome and also all of the medial portion of the lateral crus.

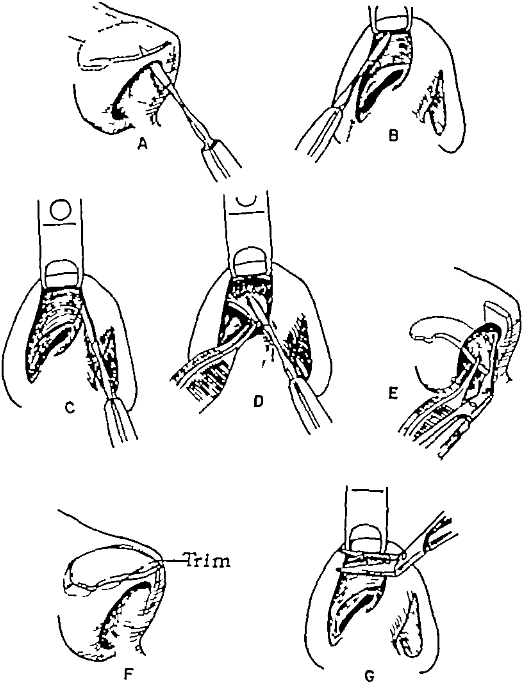

Fig 653 The Safian technique

A and B Incision along the free margin of the alar cartilage

C Incision joining the medial end of the marginal incision to the medial end of the intercartilaginous incision

D Subperichondrial separation of the cartilage from the soft tissues

E Trimming the medial border of the cartilage

F and G The cartilage is rotated downward and the protruding portion of the cartilage is trimmed

Safian (1935) and later Fred (1950) have stressed the importance of this part of the technique

The overlying soft tissues are separated from the outer surface of the cartilage (Fig 653D) and the flap of cartilage and lining vestibular skin are rotated downward and extruded The vestibular skin retracts along the cut edge of the flap forming a red margin and exposing a strip of cartilage ex cision of this cartilage along the "red line" is all that is necessary in minor modifica tions of the tip (Fig 653F) Safian also rec ommends trimming the lower edge of the

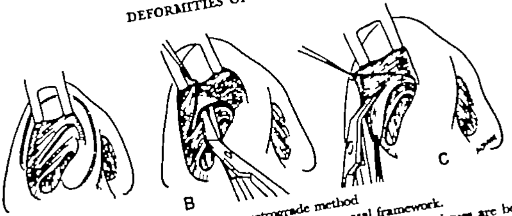

Fig 654 The retrograde method

A. Illustrating the intercartilaginous incision for exposure of the nasal framework.
B. Using small angulated scissors, the vestibular skin has been raised the soft tissues are being elevated from the cartilage.
C. The upper cartilaginous segment is resected.

cartilage at the dome (Fig 653F G) This feature of Safian s operation has not been universally accepted because a portion of the dome is sacrificed the cartilaginous excision is therefore often restricted to the upper and medial portions of the cartilage The Safian operation is particularly well suited in marked hook-deformity of the tip or in the bulbous nose due to overdevelopment of the alar cartilages. The technique offers a good exposure of the alar cartilage the excisions and contour modifications are made under direct vision

The Retrograde Technique

The upper cartilaginous segment is removed from the lateral crus through the intercartilaginous incision in order to avoid a cartilage-splitting incision. Beginning at the intercartilaginous incision the vestibular lining is elevated by subperichondrial dissection in a retrograde fashion with small angulated scissors, and the outer surface of the alar cartilage is separated from the soft tissues (Fig 654*A* *B*) Using a hook to retract the vestibular lining and grasping the upper edge of the alar cartilage with a tooth forceps (Fig 654*C*) an ellipse of cartilage from the upper segment of the alar cartilage is then resected.

The Hockey-Stick Incision Technique

This curved incision through the vestibular lining and lateral crus begins as a cartilage splitting incision which is then curved forward into the region of the dome (Fig 655) A hockey stick shaped piece of cartilage which includes the upper segment from the lateral crus and a portion of the dome can be removed through this one incision

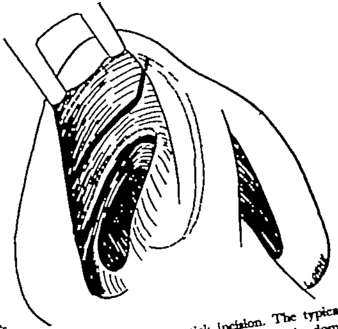

Fig 655 The hockey-stick incision. The typical cartilage-splitting incision is extended into the dome by an additional postero-anterior incision.

The Eversion Technique

This method utilizes the principle of the retrograde technique and in addition permits eversion of the lateral crus of the alar cartilage a posteroanterior counterincision extending through the dome (Fig 656*A*). It

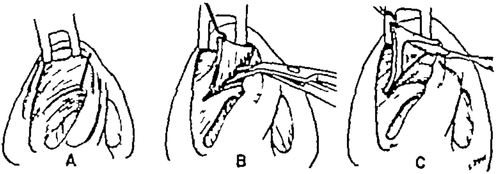

FIG 656. The eversion technique

A From the medial end of the intercartilaginous incision an additional postero-anterior incision is
B. Subperichondrial separation of the cartilage from the soft tissues.
C. The cartilage is everted into an upside-down position and the necessary incisions preparatory to lage removal are being made.

is thus possible to evert the lateral and medial crura separately and to perform the cartilaginous excisions without incising the rim (Fig 656C D)

Complete Exposure of the Alar Cartilage by Rim Incision

The ala is retracted, the instrument being placed close to the edge of the nostril Finger presure on the skin surface of the lateral crus protrudes the vestibular skin and locates the free margin of the cartilage. An incision is extended along the free margin laterally from the dome (Fig 657A) The rim of the cartilage must be differentiated from the rim of the nostril the alar cartilage border diverging from the nostril border in its lateral extension Incisions close to the nostril border should be avoided because of possible distortion particularly in the region of the soft triangle

An additional incision along the anterior margin of the columella joins the medial end of the alar rim incision at its upper termination (Fig 657B) The tip of the nose is pinched between thumb and index finger the soft triangle being puckered by this procedure At the upper end of the columellar incision the knife blade is placed beneath the puckered soft triangle to prevent cutting through it (Fig 657B)

The cartilage can be identified by its white color after the rim has been incised. Subperichondrial elevation of the soft tissues overlying the cartilage is now initi using sharp-pointed scissors, and the w shiny surface of the cartilage is exp (Fig 657C). Subperichondrial dissec does not disturb the nasal musculature soft tissues and also avoids bleeding section of the adherent perichondrium tends over the lateral crus, dome and dial crus into the area between the me crura and for a distance of about 1 along the columellar portion of the me crus the procedure is simplified by the of binocular magnifying loupes. The pedicled cartilaginous flap with the tached vestibular skin is brought down hook traction (Fig 657D). Upward trac of the alar soft tissues offers additional posure of the alar cartilage further mo cation of the cartilage can then be formed under direct vision.

Cartilage may be removed without cision through the lining (Becker 195 the cartilage and vestibular lining ma cut through in the region of the dome practiced by Fomon and Syracuse (19 The alar cartilage cannot be extruded less it has been separated from the lat cartilage by the intercartilaginous incis and from the septum by the transfi incision The intercartilaginous inci should be long enough to permit adeq mobilization of the lateral crus

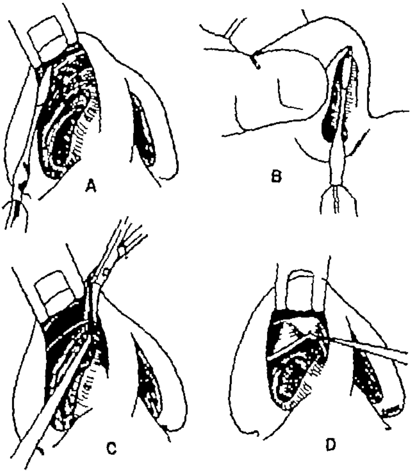

Fig 657 Technique of complete exposure by rim incision
A. Incision along the free margin of the alar cartilage.
B Incision along the anterior border of the medial crus.
C. Subperichondrial separation of the alar cartilage from the soft tissues.
D Traction exerted upon a hook placed under the dome permits extrusion of the cartilage.

The Kazanjian Exposure

The initial steps of a technique long employed by Kazanjian are similar to those used for the exposure by rim incision. The marginal incision along the rim of the lateral crus is extended medially to the medial crus (Fig 658*A* *B*) A button-knife is placed through the rim incision on the right and out through the rim incision on the left after the soft tissues have been raised from the alar cartilage on each side the knife being placed in front of the medial crura. The crura and attached columellar skin are then incised the incision extending backward and downward and joining with the transfixion incision between the septum and the columella (Fig 658C) The domes of both alar cartilages and the upper portions of both medial crura are thus separated from the lower portions of the crura both domes can then be extruded by grasping both medial crura with a forceps and retracting the soft tissues of the tip (Fig 658*D*) Sutures approximate the edges of the columellar incision

The Rethi Exposure

The technique described by Rethi (1934) employs bilateral alar cartilage rim incisions which extend to the columella and pass along the anterior margins of the medial crura. A transverse incision through the skin of the columella joins the incisions along the margins of the medial crura at the junction of the upper third and lower two-thirds of the columella (Fig 659*A*) The

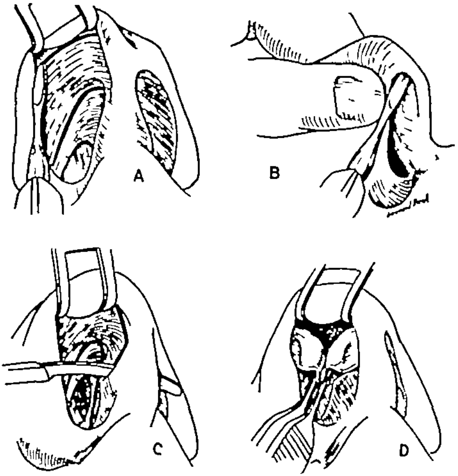

Fig. 658. The Kazanjian tip exposure technique

A. Marginal incision

B. Incision along the anterior border of the medial crus.

C. At the junction of the upper one-third with the lower two-thirds of the columella the transfixion knife severs the medial crura and the columella.

D. Both domes may thus be exposed.

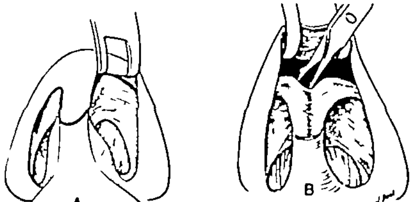

Fig. 659. The Rethi approach

A. Marginal incisions are made on each side and extended along the anterior border of the medial crus to a point situated at the junction of the upper one-third with the lower two-thirds of the columella. A transverse incision across the columella joins the two incisions.

B. The skin of the columella and tip is raised to expose the area of junction of the domes.

skin over the medial crura is then freed from the cartilages and raised exposing the area of junction of the dome with the lateral crura (Fig 659) the technique offers an excellent exposure of the nasal tip The resultant transverse columellar scar is only slightly visible if the edges of the incision are meticulously sutured.

The Mid Columellar Vertical Incision

This vertical incision frequently employed prior to the development of the intranasal technique by Joseph, affords good exposure of both medial crura and domes. DeKleine (1955) has stressed the value of this incision for exposure in wide and bifid tips because the resultant scar is not visible if accurate apposition of the wound edges is obtained.

The Butterfly Tip Incision

This incision advocated by both Kazanjian and New affords an excellent exposure of the tip Erich (1953) employed a modification of this incision to correct the tip of the deformed nose in cleft lip patients.

Techniques for Modifying the Contour of the Nasal Tip

This review of methods for obtaining exposure of the tip cartilages also includes techniques for excising cartilage from the upper portion of the lateral crus and the dome. Such cartilaginous excisions are commonly employed to complete the surgical correction of the long humped nose, in which the shortening and straightening of the convex profile line are characteristic features. The shape and size of the alar cartilages and their relationship to lateral and septal cartilages present a multiplicity of aspects, the cartilages are thick or thin and wide or narrow and show a varied shape in the area of the dome. Changes in the shape of the cartilage have been accomplished in the past primarily by excision of cartilage too much cartilage has sometimes been excised. The present trend is to be more sparing in the removal of cartilage from either the alar or the septal cartilage for excessive removal leaves the ala without adequate skeletal support. Contraction of soft tissues during the healing period occurring without an adequate cartilaginous framework may result in an irregular appearance of the tip or a pinched appearance and retraction of the nostril border Excessive removal of septal cartilage results in an open angle between the base of the columella and the base of the alae. The base of the nasal pyramid appears flat thus increasing the relative distance between the alae. Care should be exercised in planning for the amount of cartilage to be removed from the lateral crus the area of the dome, and the septum.

FIG 660 Reduction of size of broad tip

A. Preoperative view showing bulbous square shaped tip

B Result obtained after adequate excision of cartilage from the area of junction of lateral and medial crura.

It may be necessary to excise cartilage in the area of the dome in order to diminish the transverse dimensions of the nasal tip (Fig 660) The domes are in close approximation and shaped with a fairly sharp curve in tips whose contour is considered normal The wide tip has a wider curve and the domes are separated in the mid-line. The contour of the square-shaped tip is determined by the wide flat surface of the cartilaginous domes Such nasal tips require approximation of the medial crura and excision of a strip of cartilage to narrow the dome (Fig 661) Incisions in the region of the dome vary depending upon the desired modification of the tip An incision is made immediately medial to the highest point of the dome in tips which require only a change in the direction of the lateral crus in order to align the tip to the modified nasal

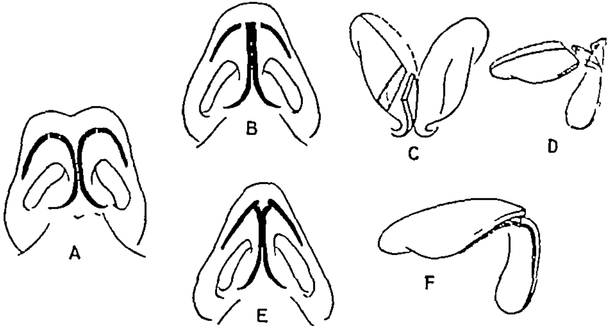

FIG 661 Schema showing methods for narrowing and raising the tip
A. In a broad tip, excision of cartilage from the domes is required.
B C and D Bifidity is corrected and the tip is raised by approximating the medial crura
E and F Overlap of the lateral crus over medial crus narrows and raises the tip The undersurface of the overlapped lateral crus must be freed of vestibular skin.

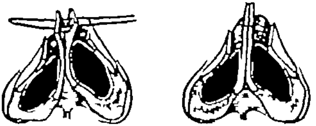

FIG 662. Kazanjian operation to raise the tip. The medial crura and a portion of each lateral crus are sutured back to-back by means of a mattress suture

dorsal profile. A triangular segment with the apex below is removed at the expense of the laterally situated cartilage (Fig 650*C D E*) if additional narrowing of the tip is required the triangle becomes trapezoid shaped with the wider base above. Both elevation and narrowing are produced by cutting through the dome and suturing the medial crura back to-back as first advocated by Kazanjian (Figs. 661 *B C D* and 662) or by overlapping the lateral crus over the medial crus (Fig 661*E, F*)

Excessive thickness of the lateral crus can be reduced by the excision of thin slices from the surface of the cartilage Some surgeons have cut windows in the alar cartilage to attain similar results others have felt that it is possible to obtain suitable contour by criss-cross cuts of the cartilage Cartilage unlike bone does not heal to itself by the formation of callus or new cartilaginous tissue the healing of sectioned cartilage occurs through the intermediary of fibrous tissue alone. The amount of fibrous tissue contraction is unpredictable and an undesirable displacement of the cut cartilaginous segments may occur Prudence must therefore be exercised in making these incisions.

Three precautions should be noted in surgical modifications of the shape of the alar cartilage (1) *Avoid raw areas resulting from removal of vestibular lining* the healing of such raw areas results in scar formation and distorting contracture (2) *Avoid excessive removal of cartilage which produces a pinched appearance* in the region of the dome excessive removal may leave a gap between the pieces of cartilage thus resulting in an unsightly groove in the skin of the tip of the nose (3) *Sharp angles and protuberances due to overlapping car*

tilaginous fragments or improperly shaped cartilaginous implants may produce external irregular prominences

A fold of excess skin may occasionally form in the vestibule this can be trimmed at a later date as an office procedure. Excess vestibular skin never manifests itself on the outer aspect of the nose The advantages of leaving excess vestibular skin are in marked contrast to the dangers of resecting vestibular skin

Tip-Remodeling Operation

This operation (Converse 1957) is based on the principle of remodeling the nasal tip with minimum resection of cartilage and is well-suited for the broad slightly bifid nasal tip (Fig 663) Cartilage is excised from the upper portion of the lateral crus through a cartilage-splitting incision if the nose requires shortening The lateral crus, the dome and the upper part of the medial crus on each side are exposed through a rim incision as previously described The connective tissue between the medial crura is removed to permit approximation of the crura. An oblique incision directed superiorly and medially is made through the cartilage of the dome only and not through the vestibular skin (Fig 664*A* *B*) The point at which this incision is placed depends upon the contour of the tip and the amount of narrowing and elevation required. By retracting the skin of the upper portion of the columella to one side the medial crura can be approximated under direct vision with forceps one branch of the forceps is placed on each side of the lateral aspect of each crus immediately below the dome The tip assumes an elevated and narrowed appearance when the domes are thus drawn together maintenance of this position and contour are the goals of the operation.

The location of the oblique cartilaginous incision is determined and the incision is made The medial crura are joined more readily because of the break in the continuity of the cartilage (Fig 661*C*) A convexity

FIG 663 Nasal tip remodeling
A. Appearance of widened and slightly bifid tip.
B. Result obtained by tip remodeling operation illustrated in Figure 664 Note the natural appearance of the tip.

or bulging can be seen lateral to the dome. An additional incision at this point achieves the correction if the tip of the nose is not unusually wide In broad tips, a strip of cartilage is outlined by parallel incisions and carefully dissected from the vestibular lining The excised strips should be triangular in shape with the base of the triangle above to avoid postoperative bulging of the upper portion of the lateral crura particularly if the nose does not require shortening and the upper portions of the lateral crura are not removed (Fig 664*B*) This procedure removes excess cartilage and permits the lateral crura to "lie down on the dorsum If the remainder of the lateral crus still exhibits an undesirable convexity one or more additional incisions through the cartilage can be employed these must not extend through the vestibular skin Three points of the technique should be noted (1) The incision at the dome is oblique, directed upward and inward to permit greater elevation of the lower portion of the tip this is a desirable feature. (2) The various fragments of cartilage produced by the incisions remain attached to the vestibular skin which is not cut through at any point, nor are any cartilaginous fragments even partly separated from the vestibular lining The continuity of the cartilaginous arch is maintained because all of the various pieces of cartilage separated by incisions remain attached to the vestibular lining The medial crura having been sutured together bring the domes into the narrowed and elevated position and the various pieces of cartilage follow because of their attachment to the

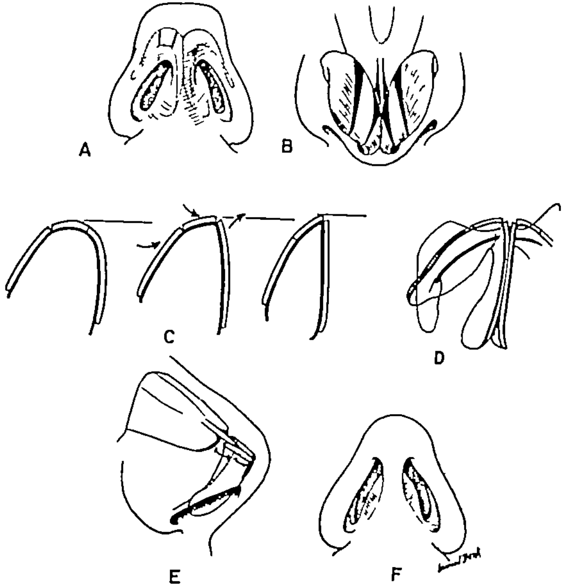

Fig 664 Tip remodeling operation

A. Location of incisions through the alar cartilage

B Another view showing shape and size of excised portions of cartilage

C Diagram demonstrating change of shape of the alar cartilage brought about by incisions through the cartilage and suturing the medial crura at the suitable level

D Technique of suture of medial crura

E Invagination technique Mucoperichondrium is removed from the septal cartilage at the septal angle The septal cartilage is then placed between the medial crura and maintained in this position by a suture

F Result obtained by the tip remodeling operation, transforming width into height

lining (Fig 613C) (3) Excised cartilaginous strips are always small for in the remodeling of the tip width is transformed into height and little removal of cartilage is required (Fig 664C to F) The tip must be adequately suspended to the septal angle before placing the sutures. The septal angle is denuded of its mucoperichondrium over interposition of mucoperichondrium between the cartilaginous structures. Coaptation of the septal angle cartilage to the posterior borders of the medial crura is assured by a correctly placed suture When postoperative drooping of the tip is anticipated, surface contact between the septal angle and the medial crura may be increased by the

of "embracing flaps" has been referred to by Fred (1950) as the invagination technique. The septal angle denuded of its mucoperichondrium over a short distance, is thinned by the excision of slices of cartilage *from each side if the cartilage is thick.* The cartilage is then invaginated between the posterior portions of the medial crura and maintained in this position by a mattress suture (Fig 664*E*) An additional mattress suture insures coaptation of the lower portions of the columella and the septal cartilage. A *mattress suture is placed at the* upper portion of the medial crura in order to approximate them in correct position (Fig 664*D*) This suture is best used with a No 14 eye-curved cutting needle. The needle is passed into the nose behind the soft triangle in the region of the recess of the vestibule the suture, which approximates both medial crura determines the resulting contour of the tip.

For these fixation sutures which do not require removal and do not result in inflammatory reaction 5-0 plain catgut is used satisfactorily throughout. Correct strapping of the tip with adhesive maintains the position of the cartilaginous segments.

Complete versus Interrupted Transfixion Incision

The routine transfixion should be avoided if the nose does not require shortening The complete *transfixion procedure* results in a degree of downward retraction of the tip due to linear contraction of the healing scar The transfixion should be interrupted in the types of noses which do not require shortening in such instances the transfixion incision extends no further than the septal angle (Fig 665*C*) When slight elevation of the tip is required the trans*fixion* incision is extended downward around the septal angle for a short distance sufficient to allow shortening of the septal cartilage in the region of the angle (Fig 665*B*) Adequate exposure is thus *obtained*

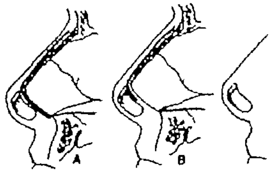

Fig 665 Complete versus interrupted tr
A Complete transfixion.
B. Transfixion interrupted below the sept
C. Transfixion interrupted at the septa

for modification of the dorsal septal line, if required

It is also necessary to extend the i around *the septal angle to permit rel* the alar cartilages from their septal ments when complete exposure by cision is required In order that the and medial crura can be brought dow view they must not be restrained b septal attachment. The intercartila incision should be long enough to adequate mobilization of the lateral c exposure.

Raising the Tip

The term raising the tip is emplo signify an increase in height or project the tip it is also used to designa change of position of the tip when th is shortened Increase in height or *tion of the tip has been discussed* ously Raising the tip in conjunction shortening the nose is achieved by ex a triangular-shaped piece of septal car from its lower *portion (Fig 666) Post*ive "drooping of the tip results fro of contact between the tip cartilages an septal angle. The invagination tech also previously described prevents drooping Loss of contact with the angle is due to (1) overshortening the tum which prevents adequate contac tween the cartilaginous structures (adequate *shortening of the septum* v

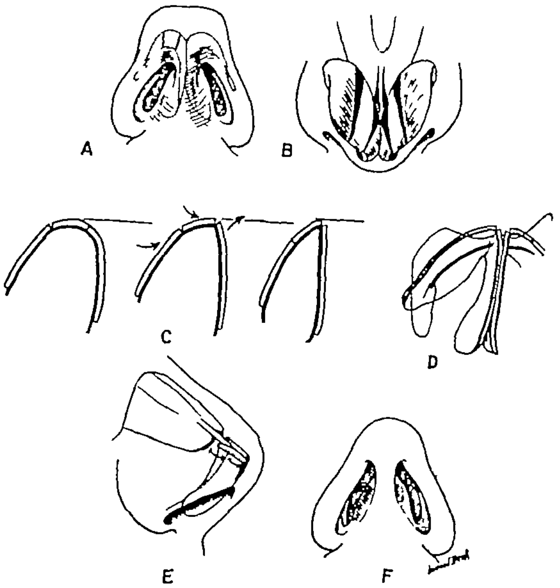

FIG 664 Tip remodeling operation.

A. Location of incisions through the alar cartilage.

B. Another view showing shape and size of excised portions of cartilage.

C. Diagram demonstrating change of shape of the alar cartilage brought about by incisions through the cartilage and suturing the medial crura at the suitable level.

D Technique of suture of medial crura.

E. Invagination technique. Mucoperichondrium is removed from the septal cartilage at the septal angle. The septal cartilage is then placed between the medial crura and maintained in this position by a suture.

F Result obtained by the tip remodeling operation transforming width into height

lining (Fig 643C) (3) Excised cartilaginous strips are always small for in the remodeling of the tip width is transformed into height and little removal of cartilage is required (Fig 664C to F) The tip must be adequately suspended to the septal angle before placing the sutures. The septal angle is denuded of its mucoperichondrium over a distance of a few millimeters to prevent interposition of mucoperichondrium between the cartilaginous structures. Coaptation of the septal angle cartilage to the posterior borders of the medial crura is assured by a correctly placed suture. When postoperative drooping of the tip is anticipated surface contact between the septal angle and the medial crura may be increased by the procedure of Rethi (1951) whose description

of "embracing flaps has been referred to by Fred (1950) as the invagination technique. The septal angle denuded of its mucoperichondrium over a short distance is thinned by the excision of slices of cartilage from each side, if the cartilage is thick. The cartilage is then invaginated between the posterior portions of the medial crura and maintained in this position by a mattress suture (Fig 664*E*) An additional mattress suture insures coaptation of the lower portions of the columella and the septal cartilage. A mattress suture is placed at the upper portion of the medial crura in order to approximate them in correct position (Fig 664*D*) This suture is best used with a No 14 eye-curved cutting needle The needle is passed into the nose behind the soft triangle in the region of the recess of the vestibule the suture which approximates both medial crura determines the resulting contour of the tip

For these fixation sutures which do not require removal and do not result in inflammatory reaction 5-0 plain catgut is used satisfactorily throughout. Correct strapping of the tip with adhesive maintains the position of the cartilaginous segments.

Complete versus Interrupted Transfixion Incision

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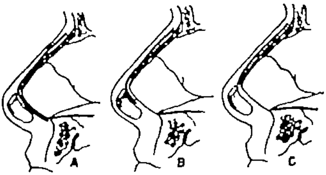


Fig 665 Complete versus interrupted transfixion
A Complete transfixion.
B Transfixion interrupted below the septal angle.
C. Transfixion interrupted at the septal angle.

for modification of the dorsal septal profile line if required

It is also necessary to extend the incision around the septal angle to permit release of the alar cartilages from their septal attachments when complete exposure by rim incision is required. In order that the dome and medial crura can be brought down into view they must not be restrained by their septal attachment. The intercartilaginous incision should be long enough to permit adequate mobilization of the lateral crus for exposure

Raising the Tip

The term raising the tip is employed to signify an increase in height or projection of the tip it is also used to designate the change of position of the tip when the nose is shortened Increase in height or projection of the tip has been discussed previously Raising the tip in conjunction with shortening the nose is achieved by excising a triangular-shaped piece of septal cartilage from its lower portion (Fig 666) Postoperative drooping of the tip results from loss of contact between the tip cartilages and the septal angle. The invagination technique, also previously described prevents this drooping Loss of contact with the septal angle is due to (1) overshortening the septum which prevents adequate contact between the cartilaginous structures (2) inadequate shortening of the septum which

FIG 666

A and C. Preoperative appearance of the patient. B and D Result obtained after modification of the profile line shortening of the septum and lateral walls, osteotomy of the lateral walls and tip surgery Correction of microgenic chin by iliac bone graft through the intraoral approach.

fails to shorten the long nose (3) shortening the septum without shortening the lateral walls, which causes a downward displacement of the tip and (4) failure to break the continuity between the medial and lateral crura which results in a recurrence of the original deformity due to the elasticity of the alar cartilage

A particular problem arises when septal support is lost by trauma or total submucous resection of the septum. The corrected position of the tip must be maintained by shortening the lateral walls through adequate excision of alar cartilage or by overlapping the alar and lateral cartilages. The curvature of the arch formed by the alar cartilage is wider than that formed by the lateral cartilages after the alar cartilages have been displaced upward. Contact can not be established unless a portion of the alar cartilages is excised to diminish the curvature of this arch.

Increasing the Projection of the Tip

This is a desirable feature in wide flat tips. When the cartilage has been cut through at the dome increase in projection can be obtained by overlapping the lateral crura over the dome and by suturing the medial crura together The new tip-remodeling operation previously described in the text gives satisfactory results in such cases and produces a natural and harmonious nasal tip

A compromise procedure is required in wide flat tips with thick skin and subcutaneous tissues, or with wide Negroid nostrils. Elevating the dorsum of the nose with a bone graft which extends under the tip is a compromise solution (Converse 1951) The lower end of the bone graft extends through the medial crura resting upon a bony columellar strut that maintains the elevation of the nasal tip (see Fig 713) The inconveniences presented by the rigidity of the nose and the danger of fracture of the bone graft are compensated for by the improvement in the nasal airway and the appearance. Flatness of the tip may require concomitant lengthening of the columella by a procedure such as the one represented in Figure 667 this not only lengthens the columella but also diminishes the width between the base of the alae. The defect produced by the mobilization of the lateral flaps is filled by advancing the base of the alae thus narrowing the nares (Fig 668)

Correction of the Excessively Pointed Tip

A sharp narrow tipped nose is due to the anatomical configuration of the domes. The dome ordinarily forms a gently curved arch at the point where the lateral and medial crura meet a pointed tip results if the crura meet at a sharp angle The technique suggested by Aufricht (1943) may be used to

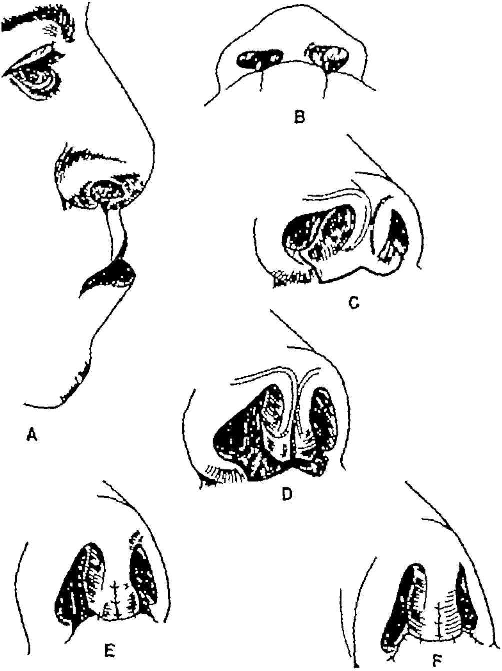


Fig 667 Elongation of the columella

A and B. Flat nose due to short columella, a condition frequently observed in patients with bilateral cleft lip.

C. Incisions outlining the flaps.

D Mobilization of flaps to lengthen columella.

F and F Closure of secondary defects by the V-Y method and medial displacement of the base of the alae.

correct this type of deformity The alar cartilages are exposed by the rim incision technique the cartilages are divided at the highest point of the dome without incising the vestibular lining A suitable segment of cartilage can then be resected if necessary two or even three small strips of cartilage are removed (Fig 669) The alar cartilages are then replaced against the overlying soft tissues The mobile segments of alar cartilage which bend downward and are maintained in position while healing assume the

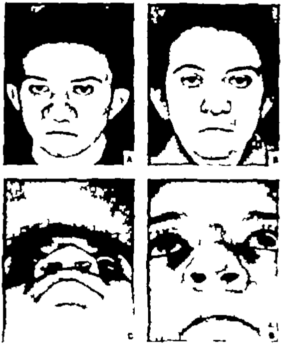


FIG 668. The flat nasal tip

A and C. Example of flat nasal tip with short columella and wide nares in patient with bilateral cleft lip.

B and D Result obtained by elongation of the columella using technique illustrated in Figure 667 and increasing the projection of the tip by technique shown in Figure 713.

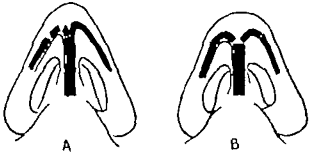


FIG 669 Correction of pointed tip (after Aufricht, 1943) Excision of small segments of cartilage eliminates the sharppointed domes.

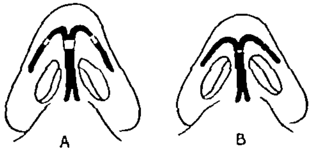


FIG. 670. Correction of prominent tip. Excision of cartilage from lateral and medial crura produces the desired recession of the tip

normal arch curvature of the dome intranasal gauze packing maintains their position

Correction of the Prominent Tip

An appreciable decrease in the projection of the tip can be obtained by the procedure for correcting the pointed tip (Fig 669). The projecting tip may require only slight modification in addition to a diminution of its prominence. Strips of cartilage removed from the medial and lateral crura lateral to the dome permit diminution of the prominent tip (Fig 670) Careful examination will occasionally reveal that the dorsum is not sufficiently projected and that the tip is in apparent protrusion Figure 671 illustrates a case in which the employment of septal cartilage over the dorsum remedied this condition (see Fig 699)

FIG 671 Correction of prominent tip by increasing the projection of the dorsum of the nose

A Preoperative view

B. Postoperative appearance after septal cartilage graft over the nasal dorsum

FIG 672. The bifid tip

A. Example of bifid tip characterized by separation between the medial crura.

B Result obtained by rim incisions and approximation of the medial crura.

The Bifid Tip

Approximation of the medial crura and the domes usually corrects the bifid tip deformity (Fig 672) Exposure of the alar cartilages through rim incisions removal of tissues between the medial crura, suitable incisions through the alar cartilages, excision of cartilage from the domes and suturing the medial crura are the various steps required for this procedure.

The Deviated Nasal Tip

The tip of the nose rarely shows marked deviation the area of junction of the two medial crura is usually in the mid line although some distortion of the lateral crura may be present due to deviation of the septal angle Pressure of the laterally twisted septal angle may cause separation of the alar cartilages with bifidity of the tip and asymmetry one lateral crus or dome being higher than the other (Fig 673C E) The pressure of the septal cartilage to one side of the columella results in lateral displacement of one medial crus with separation of the crura widening and distortion of the columella and lateral protrusion of the lower end of one of the medial crura (Fig 673E)

Straightening the cartilaginous septum is an essential procedure to correct the nasal tip in such cases

Asymmetry of the lateral crura requires removal of more cartilage from one than from the other bifidity requires approximation of the medial crura (Fig 673D F)

Correction of the Wide Columella

This condition is usually due to lateral traction upon one medial crus and to deviation of the lower edge of the septal cartilage, causing one medial crus to become separated from the other and leaving a wide gap between the cartilaginous structures. Mattress sutures through the skin tend to cause an inflammatory reaction. In order to prevent this complication, the following technique has been used successfully: an incision is made along the anterior margin of the medial crus on each side in its lower portion (Fig 674A B) the overlying skin of each medial crus is then separated from the cartilage (Fig 674C) and the soft tissues between the crura are removed. When the medial crura diverge markedly from each other a transverse incision is made in the medial crus at the point of divergence, to break the spring of the cartilage (Fig 674D) A mattress suture of 5-0 chromic catgut approximates the medial crura (Fig 674G H) the suture placed subcutaneously does not ulcerate through the skin

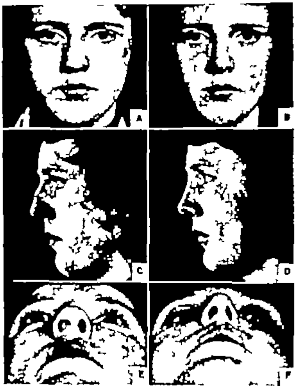


FIG 673 The nasal tip in the deviated nose

A. Widening of the tip by separation of the alar cartilages caused by deviation of the septal angle.

B Postoperative appearance

C. Hump deformity and retraction of the columella due to absence of septal support.

D Postoperative appearance after modification of the profile line and shortening of the nose.

E. Characteristic deformity of the tip with widening Note deviation of the septum and distortion of the columella.

F Postoperative appearance of the nasal tip

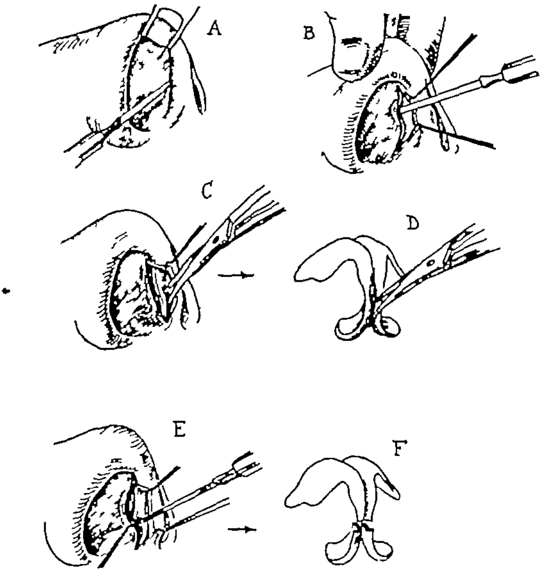


Fig 674 Narrowing the wide columella
A. Incision along the free margin of the medial crus.
B. Raising skin from lateral surface of medial crus.
C and D Separating the medial crura in the midline.
E and F Incision through each medial crus at point of divergence.
(*See continuation on next figure*)

Stage V Splinting the Nose

The nose is compressed upon completion of the operation blood is squeezed from undermined spaces by finger pressure over gauze compresses. A suture of 3-0 plain catgut is placed to approximate the septal angle and the medial crura (Fig 675) An additional suture approximates the columella and the lower border of the septal cartilage The protruding lower ends of the lateral cartilages are trimmed Non-adherent packing is placed in each nasal vestibule to support the structures of the mobilized nasal tip (Fig 676*A*) the packing must not extend into the nasal fossae proper and is not employed to prevent hematoma of the septum following submucous resection a horizontal incision along the floor of the nose is made through the left septal mucoperichondrial flap to assure drainage

The freed tip cartilages at this stage are unstable and may be easily separated by edema and blood or they may slip into faulty positions, resulting in the formation

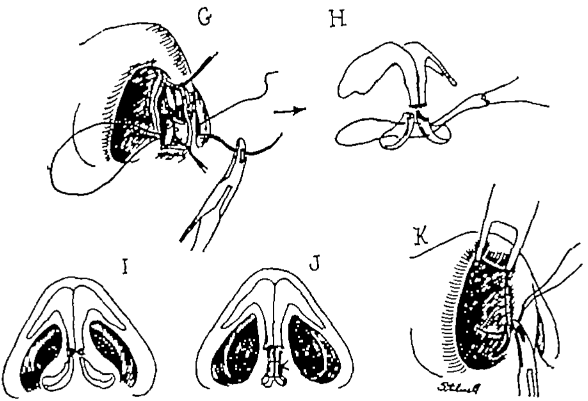


Fig 674 (*Continued*)

G and H Placing suture to approximate medial crura.

I and J Demonstrate approximation of the medial crura by suture.

K. Suturing cutaneous incision with fine catgut sutures.

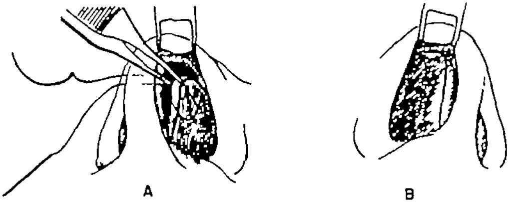


Fig 675 Suture approximating the septal angle and the medial crura

A. Straight needle used to place suture through the medial crura. A curved needle has been employed to place the suture through the septal angle.

B. Approximation of the septal angle and medial crura after tying the suture.

of grooves, asymmetry and distortion of the tip The separated parts are therefore immobilized by splinting with adhesive tape

Two strips of adhesive tape 0.5 cm. to 1 cm in width are placed around the tip of the nose. One extends across the columellar to the sides of the nose supporting the tip from below (Fig. 676*B*) The other is placed across the dorsal surface of the tip and the supratip area (Fig 676*C*) These strips of tape form a sling like loop which supports the tip against the septal cartilage and maintains the mobilized tip cartilages (Fig 676*D*) The dorsal strip of adhesive tape secures the lateral crura and obliterates any dead space between the septal angle and the soft tissues and cartilages it may be lined with inverted adhesive tape or a small piece of gauze to allow for shrinking of the skin. Additional strips placed over the dorsum (Fig.

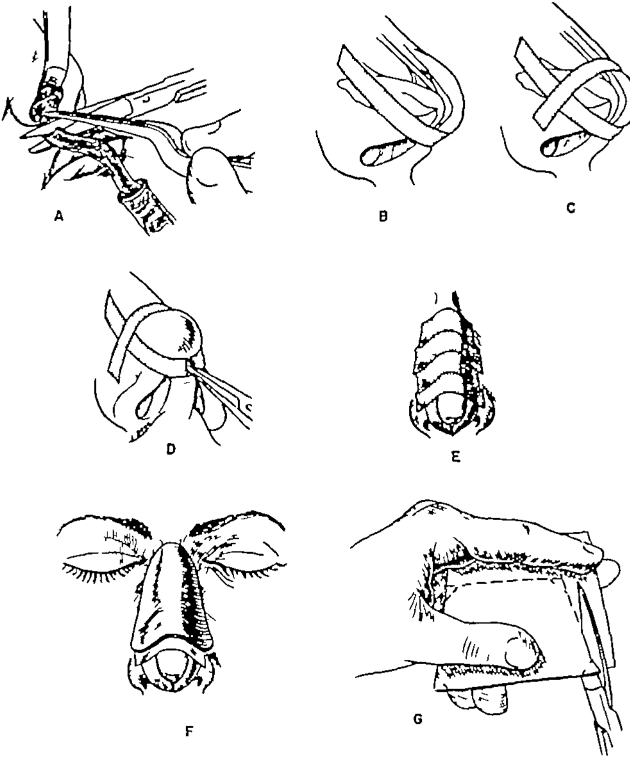


Fig. 676. Splinting of the nose

A Insertion of gauze packing
B. A strip of adhesive tape extends across the columellar surface of the tip supporting the tip from below
C. An additional strip is placed across the dorsal surface of the tip and supratip area.
D A strip placed across the columella is plicated in order to adjust its contact with the skin.
E Additional strips are placed across the dorsum of the nose.
F The lint is placed over the dorsum of the nose.
G A piece of soft metal is cut to size to serve as the carrier of the dental compound
(Figs. 676 to 678 from J M Converse in C. Jackson and C. L. Jackson *Diseases of Nose Throat and Ear* Ed. 2, W B. Saunders Co 1939)

676*E*) are covered by a piece of lint (Fig 676*F*)

The postoperative nasal splint immobilizes the tissues and maintains them against the framework thus preventing hematoma. Dental compound employed in the splinting technique, is softened in hot water and molded to the nasal pyramid avoiding pressure points. The compound is spread evenly over a suitably shaped piece of soft metal before being applied to the nasal pyramid (Fig 676*E*)

The splint should not extend below the level of the upper border of the remodeled alar cartilages and must not exert pressure on the tip forcing it downward for in most operations, an elevation of the tip is desired this is an essential precaution (Fig 677*A* *B*)

Irritation of the skin may occur under the adhesive in some individuals. A skin varnish painted on the skin before the application of the splint not only protects the skin against irritation but also enhances the sticking

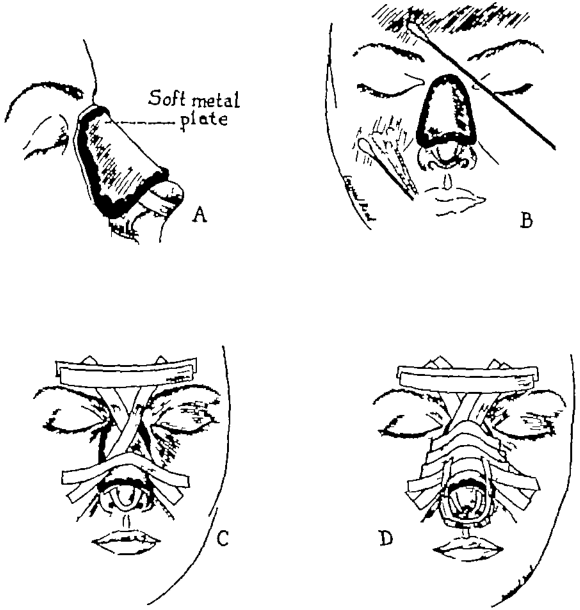


Fig 677 Splinting of the nose (*Continued*)
A. Application of dental compound mold supported by soft metal plate.
B. Application of skin varnish to skin.
C. Application of adhesive tape to maintain the splint.
D Completion of splinting

quality of the adhesive. The splint is then fastened to the face by adhesive tape (Fig 677C D)

A strip of Cellophane sticking tape, extending from ala to ala is placed across the base of the nose to prevent the loosening of the nasal packing during the postoperative period A strip of gauze facetiously referred to as the "mustache is then placed across the base of the nose and fastened with adhesive strapping (Fig 677D) the gauze is readily renewed when saturated

The Postoperative Period

The patient is placed in the Fowler position upon returning to bed the head being elevated in order to minimize postoperative oozing Pain is controlled by medication A soft diet is prescribed during the first two postoperative days to minimize active mastication which could cause loosening of the splint.

Swelling ecchymosis around the eyes and occasionally subconjunctival hemorrhage may appear within the first few hours after surgery the swelling and ecchymosis being more marked on the first postoperative day Maximum swelling and ecchymosis, which may occur 48 hours after the operation begins to subside on the second or third day The ecchymosis gradually changes from a dark bluish color to a yellowish tinge at the end of the first week Subconjunctival hemorrhage which disappears more gradually and may extend for a period of 2 or 3 weeks is a rare occurrence in the average rhinoplastic operation

Ice compresses over the eyes, though soothing for the patient, do not diminish the periocular ecchymosis or hasten its disappearance Because such compresses may loosen the adhesive which maintains the splint we have dispensed with their use.

The vestibular packing is retained for a period of 5 days to diminish the risk of hemorrhage A thick exudate which forms around the packing permits its removal without tissue trauma.

The nasal splint is removed after 5 days the adhesive strapping first line of defense, is left for an additional two-day period.

The patient is instructed to use cold cream or paraffin ointment inside the nose to soften blood clots or crusts and is also informed that the nose may appear somewhat overcorrected and swollen but that the appearance will gradually improve.

Postoperative manipulation by means of an apparatus such as the Joseph nasal clamp or other modifications of this instrument are not usually required.

Edema may persist over a period of a few months, especially in swellings of the supratip area or the root of the nose The time period is extended in direct proportion to the amount of reduction in the size of the nose. Contraction occurs more slowly in the older patient because of the loss of elastic fibers in the skin

Periocular ecchymoses are usually terminated after two weeks It has been observed that individuals with very black hair experience persistent ecchymosis around the eyes. Dark circles remained under the eyes of one such patient for a period of two months such a condition however is rare

Slight irregularities may appear after the swelling subsides causing considerable anxiety to the patient. These may occur along the dorsum of the nose at the point of junction of the lateral walls although the condition is not usually visible the patient can feel the irregularity on palpation

Patients may complain of tenderness or numbness after the operation but such sensations are usually not of long duration

Kazanjian Technique for Local Anesthesia in Corrective Nasal Plastic Surgery

To obtain anesthesia a solution containing 2 per cent procaine and epinephrine 1 50 000 is injected, beginning over the root of the nose (Fig 678) and penetrating downward and laterally toward the nasolabial fold on each side The injection is continued downward to the tip of the nose and

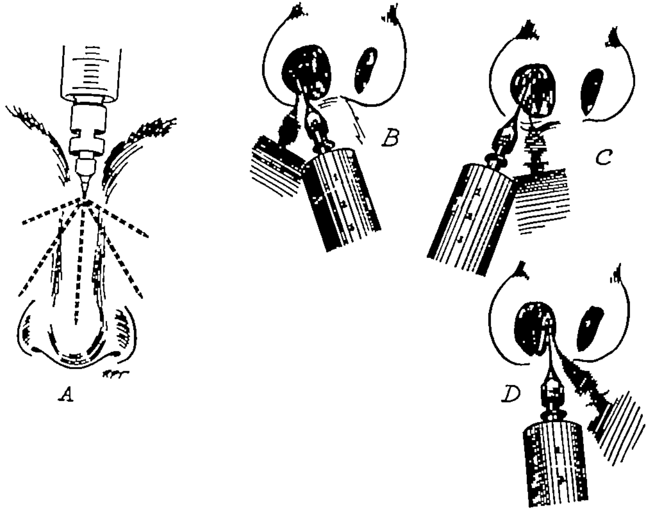


FIG 678. Infiltration anesthesia for nasal plastic operation

A. Injection made over the dorsum of the nose. Infiltration is made along the dorsum to the tip of the nose and laterally to the nasolabial fold

B Infiltration of the base of the ala.

C and D Infiltration of the membranous septum and columella.

the upper border of the septum The columella is then injected from the tip downward to the nasal spine. A subperichondrial injection is made over each side of the septum with a long needle, high and posteriorly· 10 to 15 cc. of procaine is usually required Additional anesthetic is injected into the tip of the nose when required Strips of cotton soaked in 4 per cent cocaine solution and wrung out dry are placed in each of the nasal fossae three strips, placed one over the other are usually required. Cocaine packs should never be applied to a raw bleeding area in order to avoid ensuing toxic reactions

This technique of anesthesia is usually effective for the average rhinoplastic operation including submucous resection of the septum

Kazanjian Rongeur for Hump Removal

A straight cutting bone rongeur is a convenient instrument for the resection of the dorsal osteocartilaginous hump (Fig 679) The blades of the rongeur are placed at a chosen level on the nasal hump in a plane which lies in the direction of the final cut (Fig 680) If slight digital pressure is applied through the skin over the blade of the rongeur the blades do not slip steadily increased pressure on the handles enables the blades to cut into the cartilage and bone the bone, cartilage and mucosa being cut

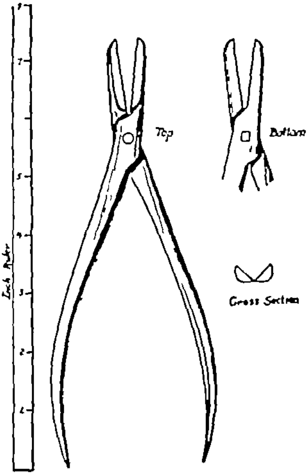


FIG. 679 Special rongeur-forceps for removal of nasal hump

(Figs. 679 and 680 from V H. Kazanjian and E. M Holmes, Arch Otol., 45:361 1947)

through in one straight line and the hump removed.

The Kazanjian rongeur is also a useful instrument to trim the cut edge of the lateral bony wall of the nose if this procedure is required.

Variations in Methods of Osteotomy of the Lateral Nasal Walls

A suitably designed angulated saw blade with sharp teeth is a satisfactory instrument *to cut through the base of the lateral wall* of the nose Saw blades should be resharpened or replaced at frequent intervals. Some surgeons prefer an osteotome or chisel to perform the osteotomy The chisel is placed in the vestibule at the edge of the pyriform aperture and tapped gently upward along the base of the lateral wall Another method originated by Mosher (1906) introduces a *narrow sharp-edged osteotome* through the skin at the upper portion of the nasolabial fold at its union with the lateral nasal fold (Fig 681*A B C D*) this area is close to the center of the lateral wall of the nose The base of the lateral wall can be severed with the osteotome as the instrument is passed upward Still another method is to make a small incision with a pointed No 11 blade within the palpebral skin of the lower lid A narrow fine-tipped osteotome is introduced through this incision to the base of the lateral wall of the nose and then downward sectioning the bone No visible scar remains after perforation of the skin if a fine-tapered narrow osteotome is used The instrument is placed in one of the transverse folds of skin near the root of the nose to complete the sectioning of the nasal *bone and the frontal process (Fig 681E)*

Deepening a Prominent Nasofrontal Angle

When the nasofrontal indentation is lacking the condition may be corrected by the following technique

In the course of the hump resection the straight saw is placed in such a fashion as to cut through the region of the root of the nose the sectioning is done on each side the saw-cuts meeting in the mid line A flat osteotome is then placed along the line of section for the removal of the hump and the osteotome is tapped upward to the upper portion of the root of the nose in a line which is a continuation of the sawline (Fig. 682*A B*)

The attachment of the bone above may be fractured by either levering the bone with the osteotome along the line of section (Fig 682*B*) or by means of a fine-tapered narrow osteotome introduced through the skin at the uppermost level of the line of section Irregularities are smoothed with a curved rasp (Fig 682*D F*) after the wedge of bone is removed (Fig 682*C*)

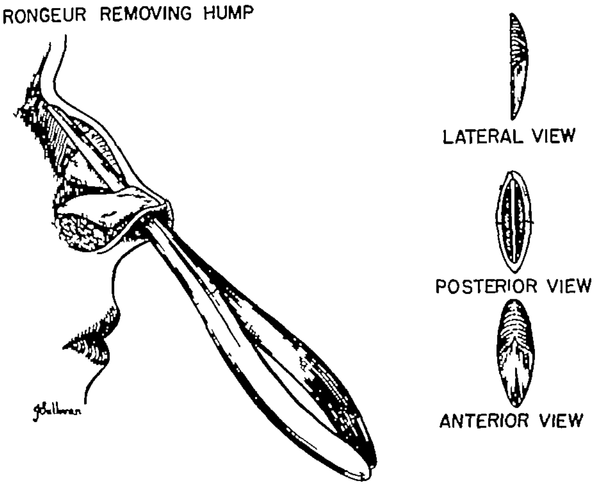


FIG 680 Technique of removing nasal hump with rongeur forceps. Various views of the resected nasal hump are shown on the right of the figure.

Additional Corrective Procedures

Wide flaring nostrils may be improved by the excision of a small wedge of tissue from the base of the nares. The hanging columella and the wide septolabial angle are deformities due to a protrusion of the excessive length of the septal cartilage into the upper lip Adequate shortening of the septal cartilage usually corrects these defects. An unusually large nasal spine may occasionally require trimming Excision of excess cartilage from these structures is required (Fig 683) when the hanging columella is due to abnormal width of the medial crura

Nasal Deviations

Nasal deviations are characteristically of traumatic origin The nasal dorsum lies in the mid-sagittal plane of the face in the undeviated nose. In partial deviations, only a portion of the nose is involved. When the entire nose is shifted or curved to one side or when the two portions of the nose veer in opposite directions as in an S-shaped deformity the condition is referred to as a generalized deviation Slight degrees of deviations are frequently due to septal deflection.

Classification of Nasal Deviations

Nasal deviations vary some rare cases are part of a generalized facial asymmetry Most deviations, however can be placed in three main classifications

1 CONGENITAL DEVIATIONS. This group may include cases of injury which have gone unnoticed in early life. A hereditary influence is suggested when the parents or grandparents have also had a similar deformity a familial relationship has been

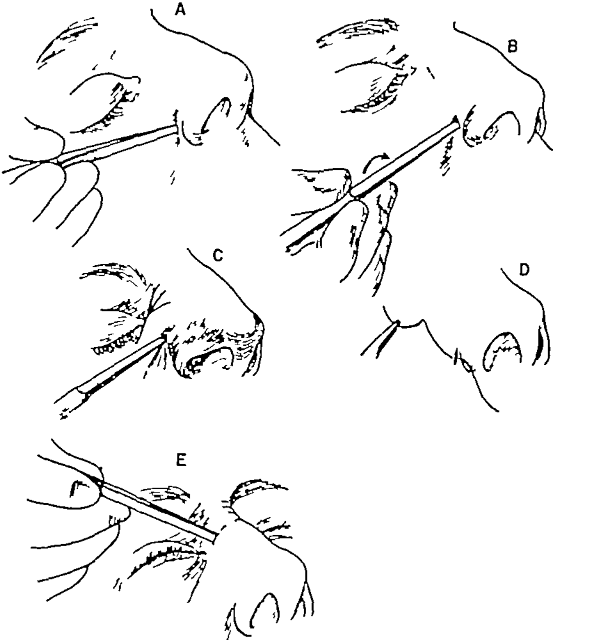


Fig. 681 Osteotomy with the osteotome

A. Osteotome is placed through the skin at the upper end of the nasolabial fold parallel to the fold.
B. Osteotome is then rotated and section of the lower part of the lateral wall is done
C. Section of the base of the lateral wall is continued upward.
D One fine silk suture is placed to close the skin wound.
E. In certain cases it may be necessary to sever the upper attachment of the lateral wall. The osteotome is placed in a transverse skin fold.

noted especially in cases of dislocation of the lower portion of the septal cartilage

2. DEVIATIONS ACQUIRED IN CHILDHOOD These deviations and deformities become more accentuated as the nose grows, and are progressively so in the adolescent. Developmental changes in the child result in greater anatomic disturbances than those which occur in the adult they affect the lateral and alar cartilages and result in distortion of the tip of the nose

3 DEVIATIONS ACQUIRED IN ADULT LIFE These deformities are due to injury in adolescence or in adult life after or near the

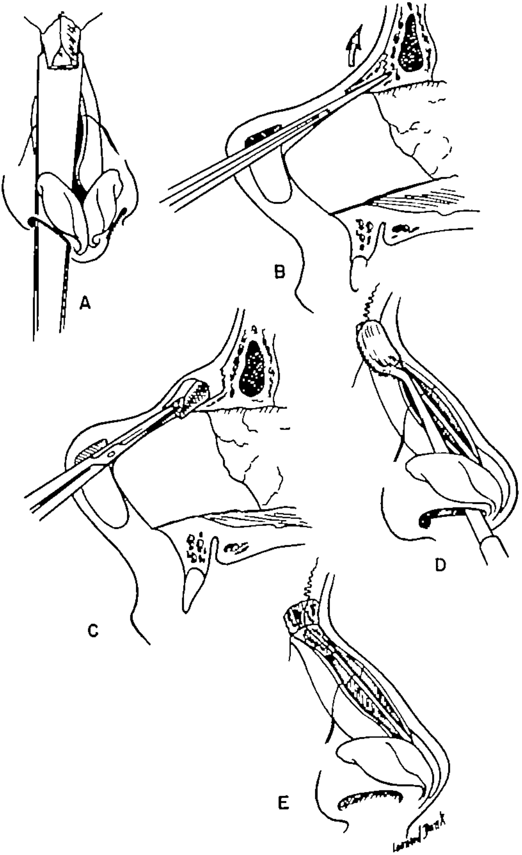


FIG 682 Deepening the nasofrontal angle

A. A wide osteotome, with rounded angles in order to avoid injury to the soft tissues is placed along the line of section for the hump removal and is tapped upward with the aid of the mallet.

B. The osteotome is levered upward fracturing the bony attachment to the frontal bone.

C. The wedge of bone is removed with the hemostatic clamp.

D Bony irregularities are smoothed with the curved rasp.

E. Deepened nasofrontal angle obtained by this procedure.

(Figs. 682 to 685 from J M. Converse in C. Jackson and C. L. Jackson, *Diseases of the Nose Throat and Ear* Ed. 2, W B. Saunders Co., 1959)

completion of nasal growth The tip of the nose usually is in the mid line, despite severe deflection of the dorsum

It is convenient to divide the nose into upper and lower portions thus partial deviations may be designated according to the affected bony or cartilaginous portions. Such a division is arbitrary because both bony and cartilaginous portions of the nose are deviated in most cases and require straightening to obtain a satisfactory result.

BONY DEVIATIONS These usually show a one-sided projection generally thin ridged and prolonged downward by a cartilaginous portion which is formed by septal and lateral cartilages and is particularly prominent in developmental types of nasal deviations. Deformities resulting from fractures of the nasal structures are varied and include such conditions as simple deviation of the bony bridge deviation with a hump due to a hypertrophic callus or overriding fragments, widening flattening saddle deformity or a combination of these. The essential anatomic feature in such conditions is the disproportionate width of the lateral walls of the nose the side of the deviation being narrower (Fig 681) Deflection of the cartilaginous structures in bony deviation is a common occurrence because of the close association of the nasal bones with the lateral and septal cartilages. Deviation of the septum often causing marked obstruction occurs frequently at the junction of the septal cartilage and the perpendicular plate of the ethmoid bone

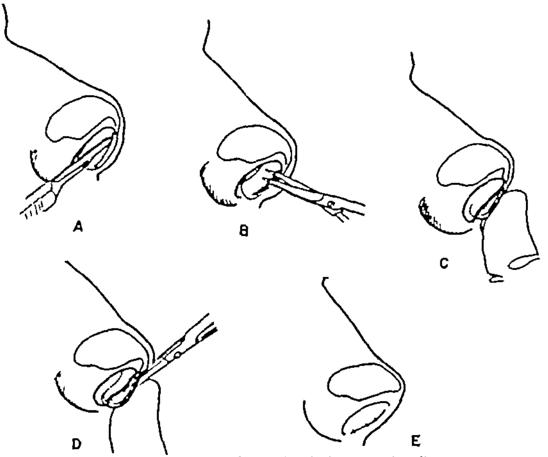


Fig 683 Technique of correcting the hanging columella

A Insertion along the free border of the medial crus.

B Freeing the cartilage from the overlying skin.

C *The columella is retruded to an adequate position of correction the excess medial crus becomes evident.*

D Trimming the medial crus.

E The incision along the free border of the medial crus is sutured with 5-0 catgut sutures

DEVIATIONS OF THE CARTILAGINOUS NOSE. Deviations are of two general varieties. In the first, the cartilaginous deviation is part of a generalized deflection of the nose (see Fig 673) Dislocation and deviation of the lower portion of the septal cartilage in the second type may be accompanied by distortion of the nasal tip

Digital palpation of the dorsum of the nose, from the nasal bones to the tip reveals the shape and position of the dorsal border of the septal cartilage finger pressure just above the tip of the nose discloses the septal angle. The dorsal portion of the septal cartilage may be displaced to one side or may present a generalized C-shaped curvature. The position and shape of the septal angle and the anterior portion of the septum can be determined by placing the tip of the thumb in one vestibule and the tip of the forefinger in the other When the nasal tip is gently elevated the upper borders of the alar cartilages can be seen protruding beneath the skin The size and shape of both alar and lateral cartilages can thus be determined

The position and shape of the septum is also confirmed by intranasal examination Hypertrophy of the middle and inferior turbinates on the side opposite the deviation is sometimes noted in patients with marked deviation of the septum.

The lateral cartilages may be asymmetrical, the cartilage on the side opposite the deviation being wider or displaced over the mid-line (Fig 685) The nasal tip feels soft to the touch when the septal angle is situated lateral to its normal position, and a depression is noted just above the tip of the nose. The septal angle may protrude beneath one alar cartilage, the protrusion resulting in asymmetry and broadening of the tip (see Fig 673) The lower septal border protruding in the narial opening causes widening or distortion of the columella from pressure against the medial crus of the alar cartilage. In another less frequently encountered condition the tip and

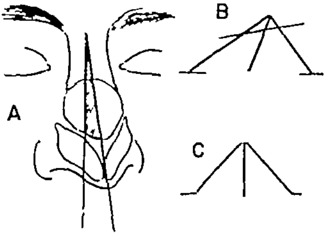


Fig 684 Inequality of the lateral nasal walls in nasal deviation.

A. The shaded area represents the amount of bone and lateral cartilage excision required to equalize the lateral walls.

B. Illustrates the excision of the hump in a beveled manner in order to equalize the lateral walls.

C. After excision of the hump the lateral walls are of equal size

septal angle are twisted to one side (see Fig 694) Absence of tip support causes depression and drooping of the tip of the nose in traumatic deformities, the septum having been crushed or fractured and the mucosa torn

Variations also occur in the angulations or curvatures of the septal cartilage in the

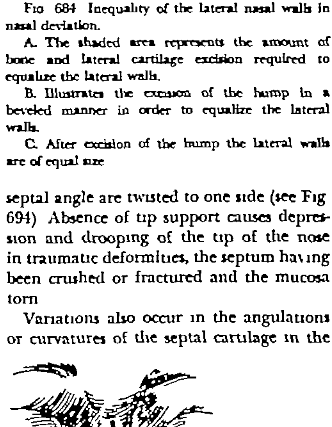


Fig 685 Drawing illustrating nasal deviation with marked deviation of the septum, represented by the thick black line note the inequality between the two lateral cartilages and the position of the septal angle beneath the left lateral crus causing an asymmetry of the tip.

anteroposterior and vertical planes. The anteroinferior portion of the cartilage may be dislocated to one side of the vomer and the upper portion of the cartilage deviated toward the opposite side. The angulation may be such that the anterior portion of the septal cartilage lies transversely across one vestibule, with the free border of the cartilage protruding into the opposite vestibule thus resulting in obstruction

More severe angulations occur about 2 cm from the free border of the cartilage or posteriorly at the junction with the perpendicular plate The posterior part of the septum is often seen to be fairly straight in severe deflection of the anterior portion of the septum The reverse condition is also noted a septum with marked posterior deflection is straight in its anterior portion

Deviations of the septum may be complicated by thickening and by vomerine spurs in traumatic conditions. Thickening is due to overlapping of fractured cartilaginous fragments producing a lamination of the cartilage and to fibrous thickening following hematoma of the septum. The curvature of angulation of the septal cartilage its dislocation from the vomer bed or a change in shape due to a fracture with overlapping of the fragments, may result in a decrease of anteroposterior or vertical dimensions of the septum

Displacement of fractured or dislocated fragments of the septal framework exerts a pull on the mucoperichondrial flaps further change in size of the septum is caused by scarring of the torn septal mucosa. Characteristic deformities such as retraction of the columella and depression or flatness of the cartilaginous dorsum above the alar cartilages accompany these changes (see Fig 673) The lower end of the septal cartilage gives support to the medial crura of the alar cartilages, thereby maintaining the protrusion of the columella Loss of the anteroposterior dimension of the septum permits retraction of the soft tissues and retrusion of the columella Loss of the vertical dimension of the septum causes a characteristic depression in the portion of the dorsum between the lateral and alar cartilages, similar to that observed after removal of septal cartilage in this area

The Role of the Septum

The correction of septal deflection is the key to the straightening of the deviated nose

The perpendicular plate of the ethmoid bone plays a relatively unimportant role in supporting the osseous nasal vault. The area where the septal cartilage joins the perpendicular plate of this bone is usually thick, constituting a resistant pillar which supports the portion of the vault formed by the lower part of the nasal bones and the lateral cartilages. The continuity of the vault is disrupted when a dorsal hump has been removed The central septal pillar remains intact and serves to stabilize the unsupported structures after the osteotomy

The cartilaginous septum plays a varying role in different types of noses. In the long thin straight nose the border of the septal cartilage may be distinctly felt along the entire dorsum to the junction of the septal angle and alar cartilages The septal angle is immediately subcutaneous in the area between the lateral and alar cartilages (see Fig 241 Chapter 8) The septal angle prevents further depression if one attempts to depress the nasal tip In other types of noses, with large alar cartilages, the angle does not support the tip and it may therefore be depressed without septal angle resistance

The lateral cartilages, intimately fused to the septal cartilages and to the nasal bones form a resistant cartilaginous vault (see Fig 212, Chapter 8) Septal cartilage may be resected as far up as this cartilaginous vault but not from between the lateral cartilages the continuity of the vault thereby remains undisturbed. A generous amount of cartilage may be resected without the contour being affected when the

attachments of the lateral cartilages to the septum are not disrupted and mucoperichondrial septal flaps are not torn In most nasal plastic operations, however a nasal osteocartilaginous hump is resected and the attachments of the lateral cartilages to the septum are disrupted.

In the supratip area the contour of the nasal dorsum is maintained by the septal angle which is joined to the lateral and alar cartilages by a thick aponeurotic membrane (see Fig 244 Chapter 8) The septal cartilage is immediately subcutaneous and removal of cartilage in this area results in flatness or depression above the tip and in some cases, drooping of the tip and retraction of the columella Although contour may be maintained in the immediate post operative period, depression in this weak triangular area occurs later Resection of cartilage should be done with prudence therefore, in the course of nasal plastic operations leaving an adequate dorsal segment and a lower buttress to assure support of the dorsum Tearing the mucoperichondrial flaps must also be avoided to prevent the downward retraction exerted by the healing lacerated soft tissues.

The usual operation for submucous resection of the septum preserves a buttress of cartilage behind the columella and a bridge along the dorsum. In other nasal deviations, however the remaining cartilage is deflected and obstruction to nasal air currents persists if not corrected. Additional surgical procedures are required therefore to correct septal deviation when associated with deflection of the external nose. Conservative procedures favor straightening the septum by incisions partial resection and repositioning of the septum. More radical techniques favor complete removal of the septal framework with subsequent replacement of cartilage between the mucoperichondrial flaps

The suitable method must be selected in each case. One cannot compare a relatively simple operation on an unscarred septum with the more difficult procedures employed for a thickened septum with adherent flaps of traumatic deformities. The technique used for the first type of case is not applicable for the second.

Our best results are obtained by a combined operation in which all of the structures of the nose, including the septum are aligned Exceptions to this rule are minor deviations affecting only the lower part of the nose in such cases a septal procedure alone is done In some complicated deviations it may be necessary to perform a minor secondary operation on the septum to correct remaining obstruction.

Corrective Surgery for Nasal Deviations

A great variety of malunited fractures of the nasal structures require a different surgical approach (1) the bones alone may be affected or (2) the cartilaginous structures may be involved.

Partial Deviations

MALUNITED FRACTURES OF THE NASAL BONES. To realign the bony structures of the nose an incision is made along the *lower border of the right lateral cartilage,* the overlying soft tissues are raised and the periosteum is elevated. A similar procedure is repeated on the opposite side and the overlying musculature is raised from the bones. Shortened muscles on the deviated side help to pull the bony structures into a deviated position.

The deviated septum *usually requires correction* the mucoperichondrial flaps are raised and the attachments of the lateral cartilages are severed from between the flaps Osteotomy of the base of the lateral walls of the nasal pyramid is performed on each side. It may be necessary in malunited fractures with pronounced overriding of the bones to comminute the bones to obtain adequate straightening A straight-guarded osteotome is placed between the septal mucoperichondrial flaps pressed to the edge of the nasal b

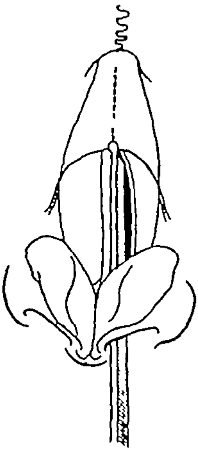


FIG 686. Illustrating the position of the osteotome placed between the septal flaps and directed to the lower border of the nasal bones in the mid line

(Figs. 686 to 689 from J M. Converse Arch. Otol., 56 671 1950)

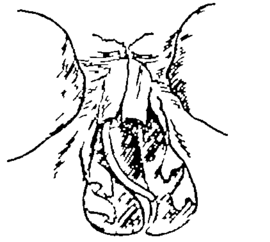


FIG 687 Drawing illustrating the position of the septum in a malunited fracture of the nasal bones. In such a case resection of the deviated portion is required to prevent the recurrence of the deviation through the spring like action of the septum against the lateral nasal wall

and into the bone to the root of the nose with the aid of a mallet separating the bones in the mid line (Fig 686) The bones are then straightened by manipulation A precautionary measure in such cases is to resect the deviated portion of the septum for it may press against the lateral wall and prevent the return of the bony bridge to the mid line (Fig 687) The corrected position is maintained by an external splint.

CORRECTION OF THE DEVIATED OR DISLOCATED LOWER PORTION OF THE SEPTAL CARTILAGE. Deviation to one side of the lower portion of the septal cartilage causes the free margin of the cartilage to protrude into the vestibule most commonly the left vestibule. Septal cartilage deviation may result in a widening of the columella due to traction of the cartilage upon one of the crura. The vomer and anterior nasal spine may be in the mid line, the cartilage being dislocated from its normal position in the vomer groove, or the vomer and nasal spine may be deviated or displaced in the same direction as the cartilage the septal cartilage and bony structures meeting at an angle.

Slight deviations of the lower end of the septal cartilage occasionally met in the course of a nasal plastic operation when shortening a long nose can be eliminated by excision of the septal cartilage.

As a rule the deviation affects a portion of the cartilage the septal angle being in the mid line Some deviations, however affect the entire anterior part of the septal cartilage the angle in such conditions, is located either on the same side as the rest of the cartilage or on the opposite side and the cartilage lies obliquely across the vestibular portion of the nose Distortion of the nasal tip is often noted in such cases.

Deviation or dislocation of the lower portion of the septum is often corrected in the course of a nasal plastic operation and is also done as an independent procedure when an external nasal operation is not

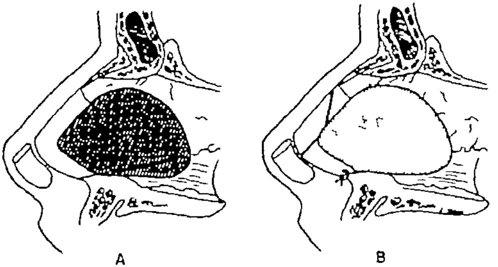


FIG 688 Correction of the deviated lower portion of the septal cartilage

A. Illustrates the amount of cartilage to be removed to correct the deviation of the septum.

B. Illustrates the oblique incision through the dorsal portion of the cartilage, the incision through the remaining lower portion of the septal cartilage and the suture anchoring the septal cartilage to the nasal spine.

required An L-shaped incision is made through the mucoperichondrium on the left side approximately 1.5 cm. from the lower border of the septal cartilage. The mucoperichondrium is raised from the left side of the septum posterior to this incision, an additional incision is made through the cartilage and the mucoperichondrium is elevated from the right side of the septum The dislocated septal framework is then resected leaving the lower deviated portion of the septum and a portion of cartilage which supports the dorsum (Fig 688*A*)

To correct a deviation of the remaining lower portion of the septum toward the left a hook is placed on the posterior border of each medial crus and traction is applied to the columella thus tensing the membranous septum The columella is moved toward the right side and the free margin of the septal cartilage is seen protruding under the skin in the left vestibule- an incision is then made along the lower border of the cartilage exposing the free margin of the cartilage Subperichondrial elevation is then performed on the *right* side of the septum (Fig 689*A* *B*) The elevation is extended subperiosteally over the vomer to the floor of the nose on the right side. The mucoperiosteum is then raised *from the vomer only on the left side* and the elevation is extended to the lateral aspect of the floor of the nose (Fig 689*B*) the mucoperichondrium covering the septal cartilage on the *left* side remaining undisturbed. A knife blade is placed under the elevated mucoperichondrial flaps on the right and the cartilage is cut through horizontally along the entire length of the vomer attachment of the septal cartilage. A pad of fibrous tissue often encountered at the junction of the septal cartilage and vomer on the right side should be excised (Holmes 1954) (Fig 689*B* *C*) If the vomer is deviated to the left side, a small osteotome placed at the junction of the vomer and floor of the nose is used to separate the vomer which is then moved to the mid line (Fig 689*C*) A deviated anterior nasal spine is sectioned and replaced in the mid line. The septal cartilage presents two curvatures toward the left, one in the frontal and the other in the sagittal plane. *Incisions* are made through the cartilage at suitable points (Fig 688*B* and 689*C*) the removal of small triangular wedges of cartilage is a technical refinement. The cartilage is swung into the mid line and retained by two mattress sutures which join the septum and the medial crura of the columella The septal cartilage may be anchored by a 4-0 chromic catgut suture looped

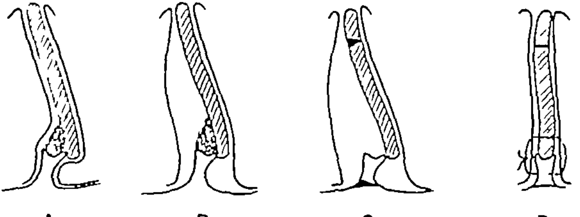


Fig 689 Correction of the deviated lower portion of the septal cartilage

A. Frontal section of the lower portion of the septal cartilage dislocated to the left of the vomer Note the fibrous tissue between the vomer groove and the septal cartilage.

B The mucoperichondrium on the right side of the septum is raised. The mucoperichondrium is also raised on the left side of the vomer the mucoperichondrium over the left side of the septum remains attached to the cartilage

C. A small wedge of cartilage is removed from the upper portion of the cartilage to permit straightening The vomer is detached from the floor by means of an osteotome and moved to the mid line The pad of fibrous tissue filling the vomer groove is removed.

D The septal cartilage is straightened replaced in the vomer groove and anchored in position by a chromic catgut suture looped around the nasal spine

around the anterior nasal spine and through the cartilage (Figs. 688*B* and 689*D*)

Holmes (1951) suggested an *oblique* incision directed downward and forward to straighten the dorsal portion of the cartilaginous framework (Fig 688*B*) and to prevent downward displacement of the dorsal cartilaginous border This incision should not extend through the dorsal border of the septal cartilage an additional precaution to avoid downward displacement of the dorsal border (Fig 688*B*)

The sectioned segment of cartilage and *the cartilage in the region of the septal angle* are maintained by the perichondrium on the left side which acts as a splint preventing the overriding of the cartilage fragments this is of practical significance when septal correction is done in conjunction with a nasal plastic operation and the position of the septal angle must be maintained The mucoperichondrium is raised from the side of the septum opposite the deviation and remains attached to the deviated side thus *preserving* the nourishment of the cartilage Contraction occurring during the healing of the raised flap tends to pull the cartilage over counteracting the tendency to resume its deviated position.

RESECTION OF THE LOWER PORTION OF THE SEPTAL CARTILAGE AND TRANSPLANTATION INTO THE COLUMELLA. The lower portion of the septal cartilage including the septal angle may be so distorted in some cases that any plan to straighten the septal framework by conservative surgery must be abandoned The lower portion of the septal cartilage is resected resection of the vomer is often included to insure adequate nasal function *To prevent retraction of the columella* a strip of septal cartilage is implanted into the columella through an incision along the anterior border of the medial crus (Fig 690*A B C*). The cartilage transplant is then placed anteriorly to the medial crura immediately beneath the skin extending downward over the nasal spine (Fig 690*F F C*)

When the lower portion of the septal cartilage is resected the septal angle is also included when this portion of the septum cannot be straightened by the methods de-

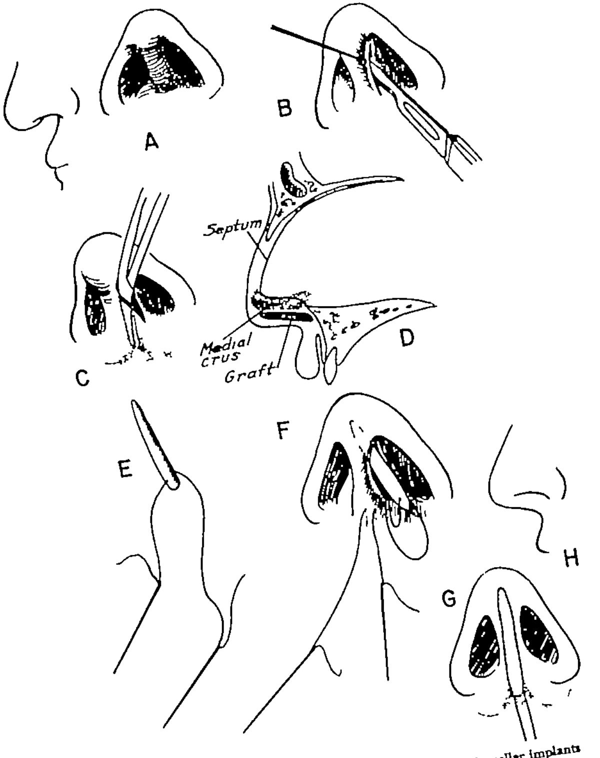


Fig 690. The anterior approach for the placing of columellar implants

A. The columella, if unsupported by the lower end of the septal catilage, may retract.
B Incision along the free margin of the medial crus.
C. The columellar skin is undermined down toward the nasal spine.
D Position of the transplant in the columella extending downward over the nasal spine.
E. Shaped septal transplant with guide suture.
F Placing the implant.
G Implant in position. The guide suture is usually removed
H Normal protrusion of the columella is restored.

(From J M. Converse, Laryngoscope, 57 16, 1957)

sed previously In such cases, postopera drooping of the tip is prevented by tening the lateral nasal walls ensuing ession of the dorsum of the nose is pre- ed by implantation of septal cartilage

Generalized Nasal Deviations

RRECTIVE SURGERY FOR COMPLETE NASAL ATION REQUIRING MODIFICATION OF THE ILE LINE. The correction of a deviated usually entails procedures which in e resection of the dorsal hump and tening the nose. We usually expose the l framework in a first stage and modify contour of the dorsum by resecting the p and trimming the superior border ie septum the nose is shortened in a nd stage by excising a triangular-shaped from the antero-inferior portion of septal cartilage The septum is then ghtened and the operation is completed steotomy of the lateral nasal walls and aping the lateral and alar cartilages. ement of the bony structures is avoided e septal procedures are done previous steotomy of the lateral walls. Success is ndent on realignment of the nasal tures to avoid recurrence of the devia

ALIZATION OF THE LATERAL NASAL LS. The nasal pyramid in cross-section iangular in shape. The lateral walls in undeviated nose form equal sides of the gle the apex is in the mid line whereas lateral walls of the deviated nasal pyra are of unequal length and the apex of triangle is located to one side of the line (Fig 681*A* *B*) The equalization ie lateral walls is essential to straighten nose Because such cases usually require tion of the laterally situated hump dization is best achieved by resecting hump along a beveled line (Fig 681*B* this technique is preferred to that origi y advocated by Joseph in which a tri e of bone is resected from the wider

TECHNIQUE OF STRAIGHTENING THE SEPTUM Additional techniques may be required to straighten the septum in the deviated nose The external nose tends to straighten when the nasal framework is freed from the de- flected septum by the transfixion procedure the spontaneous straightening of the ex ternal nose indicates that the septum is the main cause of deviation

The perichondrial flaps must be raised carefully in all septal operations to avoid tearing which may result in scar contrac ture and deformity

Submucous resection of the septum leav ing an anteroinferior and dorsal buttress, may not result in complete relief from re spiratory obstruction although a degree of straightening of the remaining portions of the septum is achieved these portions may require further correction Incisions in the remaining septal cartilage and excision of strips of cartilage are the simplest proce- dures. The remainder of the septal cartilage is exposed when the mucoperichondrium is raised as far as the dorsum the septal angle and the lower border of the cartilage. A dorsal strip 0.5 cm. wide maintains the dor sal contour and can be further straightened by a few vertical incisions (Figs. 691 and 692)

The swinging-door operation permits straightening the septal framework without resecting any part of the septum this pro- cedure should be reserved for the type of septal deflection occasionally encountered in developmental deviations of the nose (Fig 693*A* and 694) The septal deflection is characterized by an angulation of the septal cartilage from the vomer groove The principle of the operation is similar to that used to correct the dislocated lower portion of the septal cartilage The dorsal and lower borders of the cartilage are freed by the transfixion incision and the mucoperi chondrium is raised on the side of the sep- tum opposite the deviation The vomer at tachment of the septal cartilage is cut through at the point of angulation and a

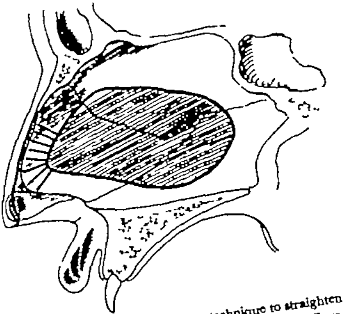
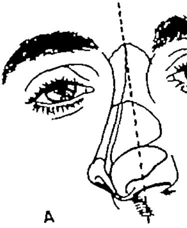


FIG 691 Multiple incision technique to straighten the curved dorsal portions of the septal cartilage. Note that the incisions do not extend through the dorsal border of the cartilage. After the incisions are made and the cartilage is straightened, overlapping cartilage is excised.

(Figs. 691 to 693 from J M Converse, Arch. Otolaryng 52.671 1950)



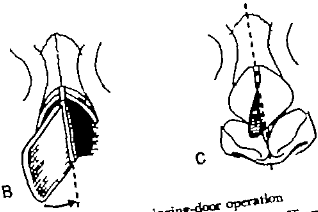


FIG 693 The swinging-door operation

A. Drawing of the deflected nose shown in Figure 694

B. A strip of cartilage resected at the site of the angulation and the freed cartilage swung into the mid-line.

C. Necessity for resecting excess width of the lateral cartilage on the side opposite the deviation

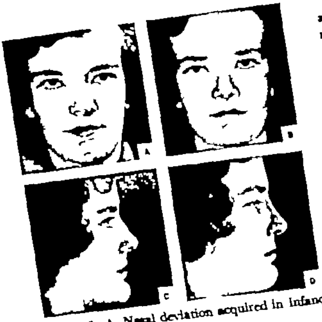


FIG 692. A. Nasal deviation acquired in infancy Note that the tip is in the midline.

B Correction obtained by realignment of the structures and straightening of the septum with the technique illustrated in Fig 691

C. Profile view before corrective surgery

D Note protrusion of columella obtained by cartilage implant as shown in Fig 690

(From Converse J M. Arch. Otolaryng 52.671 1950)

vertical incision is made in the septal cartilage which is then swung into the mid line (Fig 693B) on the side opposite the deviation Excision of excess lateral cartilage is required for pressure from this structure can result in re-establishment of the deviation (Fig 693C)

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scribed previously In such cases, postoperative drooping of the tip is prevented by shortening the lateral nasal walls ensuing depression of the dorsum of the nose is prevented by implantation of septal cartilage.

Generalized Nasal Deviations

CORRECTIVE SURGERY FOR COMPLETE NASAL DEVIATION REQUIRING MODIFICATION OF THE PROFILE LINE. The correction of a deviated nose usually entails procedures which include resection of the dorsal hump and shortening the nose We usually expose the nasal framework in a first stage and modify the contour of the dorsum by resecting the hump and trimming the superior border of the septum the nose is shortened in a second stage by excising a triangular-shaped piece from the antero-inferior portion of the septal cartilage The septum is then straightened and the operation is completed by osteotomy of the lateral nasal walls and reshaping the lateral and alar cartilages. Movement of the bony structures is avoided if the septal procedures are done previous to osteotomy of the lateral walls. Success is dependent on realignment of the nasal structures to avoid recurrence of the deviation.

EQUALIZATION OF THE LATERAL NASAL WALLS. The nasal pyramid in cross-section is triangular in shape. The lateral walls in the undeviated nose form equal sides of the triangle the apex is in the mid line whereas the lateral walls of the deviated nasal pyramid are of unequal length and the apex of the triangle is located to one side of the mid line (Fig 684*A* *B*) The equalization of the lateral walls is essential to straighten the nose Because such cases usually require resection of the laterally situated hump equalization is best achieved by resecting the hump along a beveled line (Fig 684*B* *C*) this technique is preferred to that originally advocated by Joseph in which a triangle of bone is resected from the wider side

TECHNIQUE OF STRAIGHTENING THE SEPTUM. Additional techniques may be required to straighten the septum in the deviated nose The external nose tends to straighten when the nasal framework is freed from the deflected septum by the transfixion procedure the spontaneous straightening of the external nose indicates that the septum is the main cause of deviation.

The perichondrial flaps must be raised carefully in all septal operations to avoid tearing which may result in scar contracture and deformity

Submucous resection of the septum leaving an anteroinferior and dorsal buttress, may not result in complete relief from respiratory obstruction although a degree of straightening of the remaining portions of the septum is achieved these portions may require further correction Incisions in the remaining septal cartilage and excision of strips of cartilage are the simplest procedures. The remainder of the septal cartilage is exposed when the mucoperichondrium is raised as far as the dorsum the septal angle, and the lower border of the cartilage A dorsal strip 0.5 cm. wide maintains the dorsal contour and can be further straightened by a few vertical incisions (Figs. 691 and 692)

The swinging-door operation permits straightening the septal framework without resecting any part of the septum this procedure should be reserved for the type of septal deflection occasionally encountered in developmental deviations of the nose (Fig 693*A* and 694) The septal deflection is characterized by an angulation of the septal cartilage from the vomer groove. The principle of the operation is similar to that used to correct the dislocated lower portion of the septal cartilage. The dorsal and lower borders of the cartilage are freed by the transfixion incision and the mucoperichondrium is raised on the side of the septum opposite the deviation The vomer attachment of the septal cartilage is cut through at the point of angulation and a

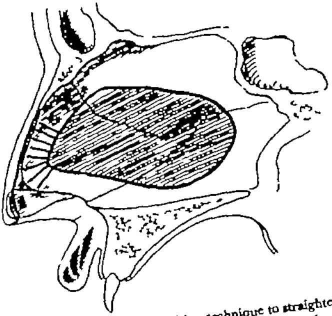

FIG 691 Multiple incision technique to straighten the curved dorsal portions of the septal cartilage. Note that the incisions do not extend through the dorsal border of the cartilage After the incisions are made and the cartilage is straightened overlapping cartilage is excised

(Figs. 691 to 693 from J M. Converse, Arch. Otolaryng., 52:671 1950)

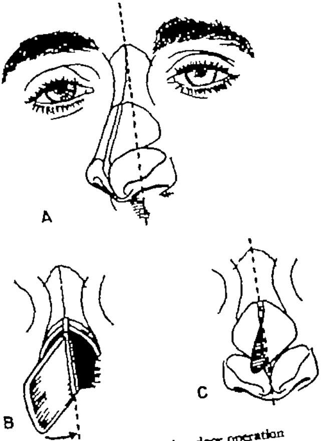

FIG 693 The swinging-door operation

A. Drawing of the deflected nose shown in Figure 694

B. A strip of cartilage resected at the site of the angulation and the freed cartilage swung into the mid line.

C. Necessity for resecting excess width of the lateral cartilage on the side opposite the deviation.

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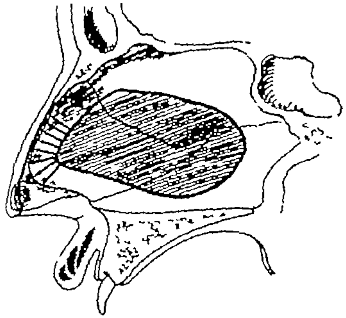

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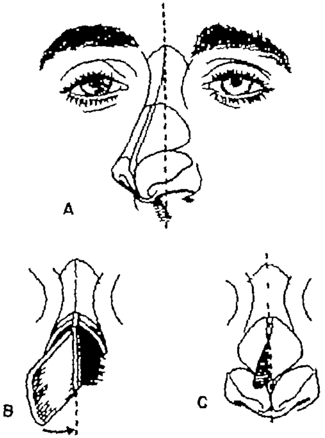
(Figs 691 to 693 from J M. Converse, Arch. Otolaryng 52 671 1950)



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C. Profile view before corrective surgery

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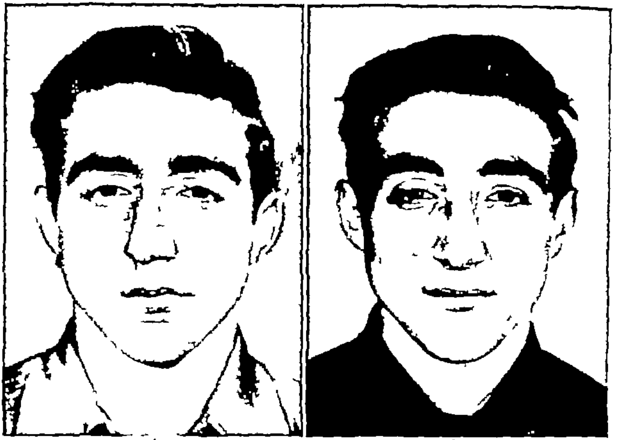

A B

FIG 694

A. Deflected nose of traumatic origin.

B. Straightening obtained after realignment of the structures. The septum was straightened with the technique illustrated in Figure 693.

ment replacement of the cartilage in the mid line Raising the mucoperiosteum from the vomer and from the floor of the nose and then incising the lining at the lateral portion of the nasal floor permits advancement of the mucoperiosteum toward the septum A patient in whom correction was obtained by the swinging-door technique is shown in Figure 691

RESECTION AND TRANSPLANTATION OF SEPTAL CARTILAGE A deviated nose with a marked S-shaped or C-shaped curvature of the dorsal border of the septal cartilage cannot be corrected by conservative methods of treatment The entire twisted cartilage must be resected and a portion replaced to provide support for the dorsum The septum is shortened, if necessary following the transfixion procedure and modification of the profile line The mucoperichondrial flaps are then raised and the septal framework is examined.

The hump usually small in this type of case is caused by the downward displacement of the cartilaginous portion of the dorsum *The lateral cartilage attachments are* preserved when this small hump which may be described as a pseudohump is removed the remaining attachments of the cartilage should not be separated from the septum The procedure avoids the collapse of the septal mucoperichondrial flaps which may occur if the entire septal framework is exposed and the lateral cartilages are cut through and separated from the septum in the usual manner Excision of tissue from one lateral cartilage in order to equalize both a procedure often necessary in deviated noses may be accomplished from above without cutting through the mucous membrane (Fig 695) The preservation of the

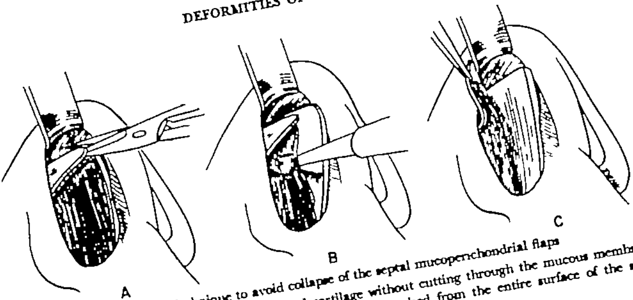


Fig 695. Technique to avoid collapse of the septal mucoperichondrial flaps

A Lateral cartilage is severed from the septal cartilage without cutting through the mucous membrane.

B. The mucoperichondrium overlying the septum may be raised from the entire surface of the septal cartilage.

C. The septal mucoperichondrial flap remains attached to the lateral cartilage.

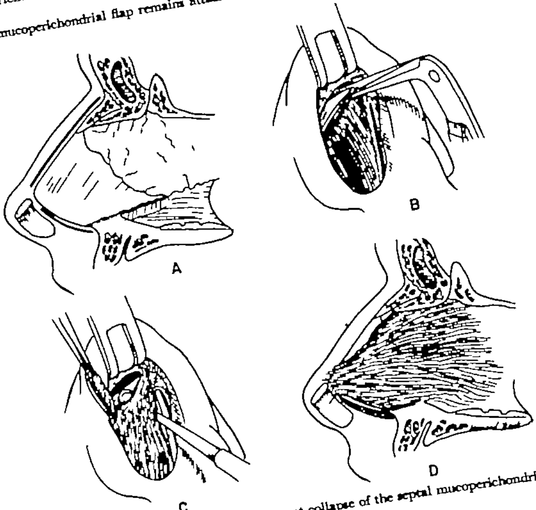


Fig 696. The interrupted transfixion to prevent collapse of the septal mucoperichondrial flaps

A The transfixion is interrupted at the septal angle.

B The lateral cartilage and the underlying mucous membrane are severed from the septum.

C. Because of the interrupted transfixion the septal mucoperichondrial flap remains attached to the membraneous septum.

D Another view showing the anterior attachment of the septal mucoperichondrial flap.

(Figs. 695 to 701 from J M. Converse in C. Jackson and C. L. Jackson, *Diseases of Nose Throat and Ear* Ed. 2, W B. Saunders Co., 1959)

remaining attachments of the cartilages maintains a degree of continuity along the dorsum for in these badly deviated noses a few millimeters of septal cartilage should be left between the lateral cartilages, if feasible *to preserve the continuity of the* vault The small strip forms a bed for a free cartilaginous transplant. Another procedure employed to avoid collapse of the septal flaps is to interrupt the transfixion at the septal angle leaving an attachment of the flap (Fig 696)

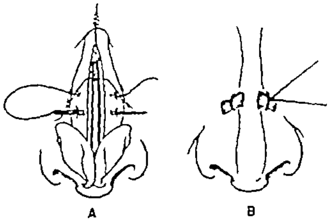


Fig 697 Method of fixation of septal transplant to the lateral cartilages.

A. After the septal cartilage transplant has been replaced between the mucoperichondrial flaps, fixation to the lateral cartilages is obtained by means of an externally placed mattress suture

B. Method of tying the mattress suture on the surface of the skin over a small piece of gauze

Resection of the septal cartilage is then done in one piece to obtain transplants of adequate proportions. It is possible to se*cure a sufficiently long straight piece of car*tilage for a suitable transplant even in the most deviated septal cartilage The resected cartilage is placed in a moist saline sponge until all the other procedures of the nasal plastic operation have been completed the cartilage transplantation is the final procedure.

One method for transplanting septal cartilage over the dorsum of the nose consists of placing a straight piece of cartilage between the septal flaps and suturing the lateral cartilages to the transplant (Figs. 697 and 698) this technique may result in a cartilaginous dorsum with a sharp ridge. A second and preferable method of cartilage transplant to support the dorsum consists of placing the graft in the mid line over the lateral cartilages (Figs. 699 and 700)

The cartilage graft is introduced through one of the incisions previously made to correct the tip and is placed over the lateral cartilages. The dorsal septal cartilaginous transplant may be placed with precision by the technique illustrated in Figure 699 Two

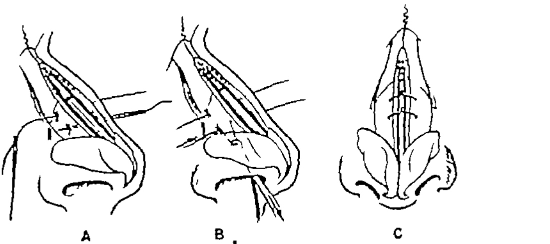


Fig 698 Anotl ... for fixation of ... int to the lateral cartilages

A. Catgut sutures intro... the skin ... lateral cartilages and the septal trans
plant

B The catgut sutures ar... nasal cavi... ook

C. The sutures are tied ... ring f... transp' ... lateral cartilages

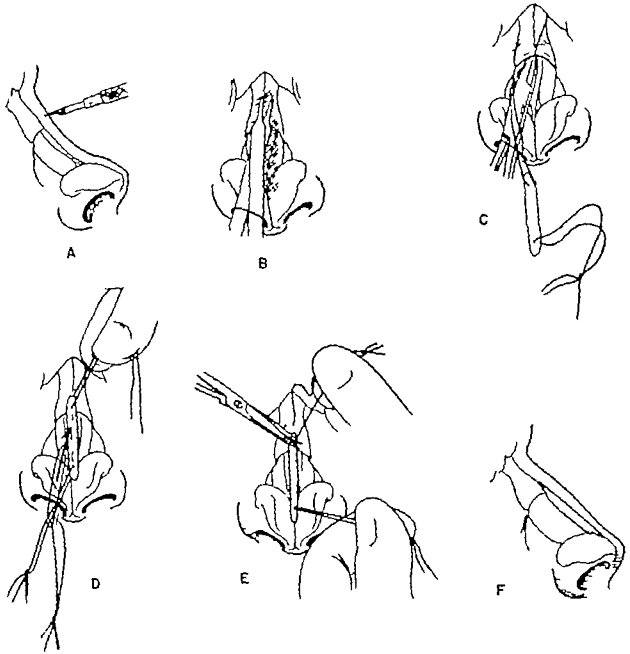


FIG 699 The technique of transplantation of septal cartilage to the dorsum of the nose

A. Two ink dots on the skin indicate the upper and lower limits of the transplant.

B. Scissors undermining the area over the dorsum to be occupied by the transplant.

C. The transplant is held by guide sutures the upper guide sutures are introduced in position by means of a straight needle which pierces the skin through the upper ink dot.

D Traction exerted upon the upper guide sutures introduces the transplant into its predetermined position along the dorsum of the nose

E. Guide sutures are removed.

F The operation is completed.

(From J M. Converse, Arch. Otolaryng. 52 671 1950)

ink dots are made over the dorsum at points between which the cartilage is to be placed. The dots indicate the upper and lower limits of the implantation site (Fig 699*A*) Sutures of 4-0 plain catgut with straight cutting needles are placed at each extremity of the cartilaginous implant. The needles carrying the upper traction suture are placed into the subcutaneous pocket and out through the skin (Fig 699*C* *D*) the needles with the lower traction sutures are also placed into the pocket and the sutures

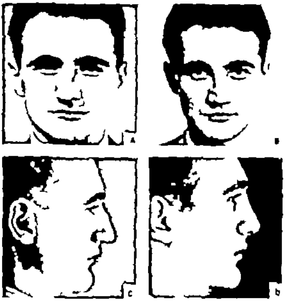


FIG 700

A. Traumatic nasal deviation with protrusion of the septal angle beneath the right alar cartilage causing distortion of the tip.

B. Result obtained by realignment of the structures. The septal cartilage was resected completely and *strips of cartilage were transplanted over the dorsum, as illustrated in Figure 699*

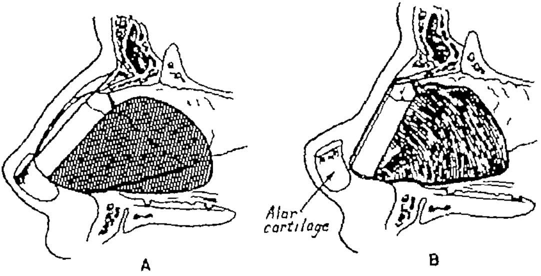
C. Profile view of the nose showing retraction of the columella

D After corrective surgery and use of columellar cartilaginous implant with the technique illustrated in Figure 690

are tightened These sutures can be tied over a piece of gauze on the dorsum of the nose or they can be cut and removed after the operation has been completed, and before the adhesive strapping is placed over *the nose (Fig 699E F) The advantage of* fine plain catgut is 2 fold the retained sutures may be left to dissolve spontaneously and the nasal splint need not be removed. Another procedure can be employed instead of exerting force on the suture which may cause displacement of the transplant the ends of the suture are held between the thumb and index finger while the flat blades of the scissors are brought down to the skin The suture is then cut close to the skin by applying pressure against the skin and upward traction on the suture (Fig 699F) As the tension is released the cut ends of the suture disappear beneath the skin these are absorbed without causing tissue reaction Silk or Nylon sutures occasionally break and remain under the skin causing tissue reaction and in some cases, inflammation and suppuration

COLLAPSE OF THE SEPTUM After a typical submucous resection the remaining portion of the septal framework is supported by (1) the anterior buttress of septal cartilage (2) the perpendicular plate of the ethmoid and (3) the lateral cartilages.

A disturbing situation may arise in the course of a corrective nasal plastic operation which requires hump removal and lateral osteotomy when extensive resection of the septum is also necessary The supporting buttress is eliminated in a submucous *resection in which the lower portion of the* septum is removed Because the cartilaginous vault formed by the septal and lateral cartilages is disrupted by resection of the *hump the remaining dorsal portion of the septal cartilage* remains connected posteriorly to the thin perpendicular plate of the ethmoid only The perpendicular plate may *be fractured after osteotomy of the lateral* walls. Loss of this remaining support results in collapse of the septal framework into the nasal cavity (Fig 701*A B*) This condition may be remedied by *suspending* the septal cartilage A 4-0 plain catgut suture is prepared with a straight needle on each end One of these needles is introduced *through the full thickness of the loosened* septum each of the needles then perforates the skin of the dorsum of the nose at a point immediately below the lower border of the nasal bones. *Upward traction (Fig 701C)* upon the suture raises this portion of the septum to the correct level A similar procedure is done in the region of the septal angle traction sutures are *placed through* the skin of the dorsum of the nose immediately above the tip in the region of the angle These traction sutures maintain the septal cartilage until more permanent measures secure it in the corrected position An adequate piece of septal cartilage if avail



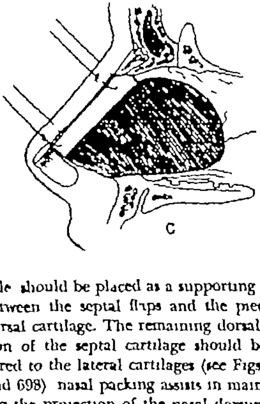


Fig 701 Collapse of the septum

A. Illustrates the remaining portion of the septum after excision of the dorsal hump and the necessary resection of the lower end of the septal cartilage. The remaining septal framework is supported only by the perpendicular plate of the ethmoid.

B. Fracture of the perpendicular plate of the ethmoid resulting in a downward displacement of the remaining septal framework. This may occur after the osteotomy of the lateral nasal walls.

C. Method for suspending the septal framework with sutures until adequate measures can be taken to maintain the fixation of the septal cartilage.

able should be placed as a supporting strut between the septal flaps and the piece of dorsal cartilage. The remaining dorsal portion of the septal cartilage should be sutured to the lateral cartilages (see Figs. 697 and 698) nasal packing assists in maintaining the projection of the nasal dorsum.

Corrective Surgery for Complete Deviations Which do not Require Modification of the Profile Line

The nasal framework is sometimes deviated from the mid line in both upper and lower portions without changing the profile line. A modified corrective procedure is used in such cases.

An incision is made at the lower border of the lateral cartilage on the right side and the soft tissues are elevated from the lateral cartilage by sharp dissection with a double-bladed Joseph knife. Another incision is then made with the tip of the Joseph knife through the periosteum covering the nasal bone, and the periosteum is raised. Similar procedures are undertaken on the left side

A submucous resection of the deviated septum is done. Osteotomy of the base of the lateral walls of the nose is performed as previously described (see Figs. 643 to 646)

A guarded straight osteotome is now placed between the mucoperichondrial flaps of the septum and is directed upward until the operator feels the lower border of the nasal bones in the mid line with the tip of the instrument (Fig 702) The osteotomy line is cut in the mid line at the junction of the nasal bones, using a mallet to tap the

osteotome upward the bones are thus separated and can be manipulated into a realigned position because they have been completely freed from the covering periosteum and musculature

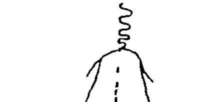


FIG 702 Osteotome placed between the septal mucoperichondrial flaps and applied to the lower border of the nasal bones preparatory to severing the nasal bones in the mid-line

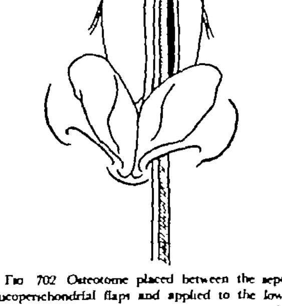


FIG 703 Corrective surgery for malunited fracture of the nasal bones

A Appearance of patient with marked deviation of the nose as the result of malunited fracture

B Result obtained with the technique illustrated in Figure 702.

(From J M Converse Arch Otolaryng 52 471 1950)

Nasal packing is used to approximate the septal mucoperichondrial flaps and a molded nasal splint is employed to maintain the alignment of the reduced fragments. Figure 703 illustrates a case of malunited fracture of the nasal bones treated by the technique described.

Depression of the Nasal Dorsum

Nasal depressions may affect either the cartilaginous or osseous portions of the nasal framework The condition is usually referred to as a saddle-nose deformity when both bony and cartilaginous portions are depressed and the projection of the tip of the nose is preserved

When injury involves the entire nose the resulting deformity is a flat nose which may be further complicated by widening deviation or shortening Conditions arise which interfere with function these include thickening of the septal cartilage and collapse of the lateral and alar cartilages. The septum may attain a thickness of over 1 cm in cases of repeated fracture and hematoma, a condition frequently observed in pugilists.

Depression of the Cartilaginous Dorsum

Various degrees of depression are observed in the cartilaginous portion of the nose following injury to the nasal pyramid loss of septal support or scar contracture of the mucoperichondrial flaps The dorsum of the nose may show a pseudohump due to depression of the cartilaginous dorsum accompanied frequently by widening of the bony bridge and drooping of the nasal tip.

Satisfactory correction of this type of deformity can often be obtained by resecting the pseudohump narrowing the nasal bridge by osteotomy of the lateral walls and shortening the nose by excision of cartilage from the anterior border of the septal cartilage and the alar cartilages (Fig 701)

Other types of procedures are required in more accentuated depressions these include the flying wing operation or a septal cartilage graft

A B

C D

Fig. 704 Nasal deformity following malunited fracture resulting from an automobile accident

A. Flat nose with widening of the bony bridge.

B. Flattening of the bridge with depression over the lateral cartilage and drooping of the tip.

C. Correction of deformity by narrowing and shortening the nose.

D. Correction of nasal profile obtained by operative proce

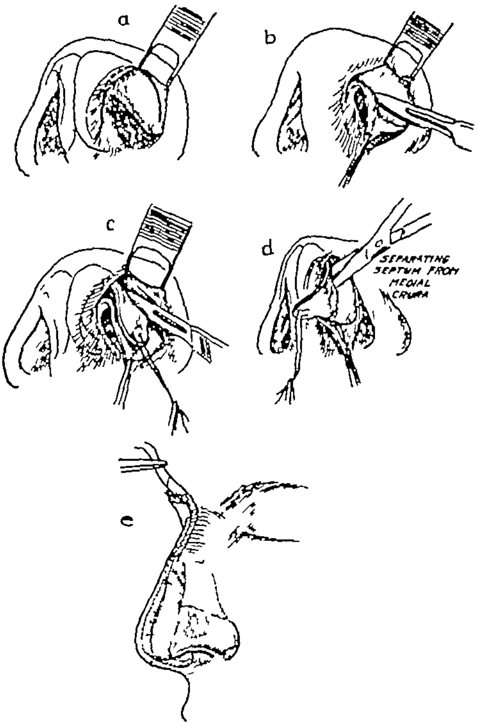


FIG 703. The flying wing procedure

A. A vestibular incision is made along the free margin of the alar cartilage

B The vestibular lining is carefully separated from the alar cartilage.

C. The upper surface of the alar cartilage is separated from the overlying skin and a flap of alar cartilage is made with a narrow pedicle at the tip

D The flap of cartilage is further freed by sectioning the tissue between the septum and medial crus

E. The two cartilaginous flaps are joined together over the dorsum of the nose and held in position by sutures passed through the skin.

THE FLYING WING OPERATION (KAZANJIAN) Alar cartilages are used to correct moderate saddle deformity in the region of the lateral cartilages. The type of deformity most suited to the use of this procedure is characterized by a normal bony contour associated with depression of the cartilaginous bridge, well-developed alar cartilages, and a drooping tip This operation utilizes the alar cartilages to correct the depression of the bridge, and also to shorten elevate and narrow the tip of the nose

A vestibular incision is made along the free margin of the alar cartilage and the vestibular lining is raised from the cartilage (Fig 705) The alar cartilage is freed from the overlying skin forming a long cartilaginous flap with a narrow pedicle attached to the tip (Fig 705*A B*) Some of the fatty pad of the ala may be included to increase the length of the flap a similar procedure is performed on the opposite side. The alar cartilages are freely manipulated through the vestibular incisions and the wings are transposed from a horizontal to a vertical position over the dorsum. The medial edges of the alar cartilages are maintained with buried sutures a mattress suture is passed through the distal end of each alar flap (Fig 705*C D*) The free ends of the sutures are passed through the skin near the root of the nose and sutured together over a small piece of gauze (Fig 705*E*) The two alar cartilages thus transposed from horizontal to vertical position are similar to free grafts, except that the cartilaginous flaps are pulled upward, the tip is elevated the alae narrowed, and the nose shortened (Fig 706)

SEPTAL CARTILAGE GRAFTS. The technique illustrated in Figure 699 is employed when transplantation of septal cartilage is required in more accentuated depressions of the cartilaginous bridge.

If septal cartilage has been destroyed through trauma or is not available as the result of a previous submucous resection sufficient autogenous cartilaginous material

Fig 706

A. Depression of the cartilaginous bridge

B. Result obtained by flying wing operation illustrated in Figure 705

can be obtained from cartilage removed from the ear Costal cartilage, removed with a Kelly gouge is used for larger cartilage grafts.

Osteocartilaginous Nasal Depression Saddle nose and Flat Nose

Nasal deformities requiring bone grafting include such depression deformities as saddle-nose, which involve the bony and cartilaginous vault or flatness of the nose, with loss of septal support and contraction of the nasal lining (Fig 707)

Various types of grafts and implants have been employed for nasal contour restoration these include autogenous cartilage, preserved homogenous and heterogenous cartilage and foreign materials such as tantalum and the acrylics. Fresh autogenous cartilage tends to curl. Homogenous or heterogenous cartilage may initiate an inflammatory reaction violent enough to cause early rejection by the tissues such grafts are progressively absorbed in a high proportion of cases. Although *inert materials* may be tolerated by the tissues for a varying period of time, they are often extruded because of tissue irritation around the implant especially when implanted in areas of functional stress or subjected to muscular movements or to trauma the rejected implant leaves a bed of dense fibrous tissue complicating further reconstructive procedures. All of these implants, including

A B C

FIG 707 Nasal depressions

A Photograph showing traumatic depression of the lower cartilaginous portion of the nose Note the drooping of the tip.

B. Typical saddle-deformity of the nose involving both bony and cartilaginous portions.

C. Flat nose resulting from widening of the bony bridge and loss of septal support of the lower part of the nose.

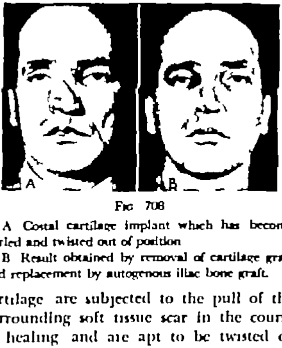


FIG 708

A Costal cartilage implant which has become curled and twisted out of position

B Result obtained by removal of cartilage graft and replacement by autogenous iliac bone graft.

cartilage are subjected to the pull of the surrounding soft tissue scar in the course of healing and are apt to be twisted or rotated from their original position during the weeks following implantation (Fig 708)

Bone grafts, when placed in contact with living bone cause no tissue reaction They consolidate with the host bone and become incorporated into the bony facial framework (Fig 709) Bone grafting is contraindicated only if contact between the bone graft and living bone cannot be achieved

Nasal bone grafts become consolidated with the underlying nasal bones, thus preventing loosening or deviation Consolidation with the nasal bones maintains the projection of the lower part of the graft The bone graft may be fractured because of its rigidity an unusual occurrence but usually consolidates uneventfully

Costal cartilage autografts survive satisfactorily and do not require the same contact with the nasal bony framework as bone grafts. Cartilage however tends to curl and bend and to be twisted away from its original position by the pull of adjacent scar tissue (Fig 708) The cartilage implant cannot resist this pull for consolidation with the underlying bony structures does not occur

The Nasal Bone Graft Operation

ILIAC BONE GRAFT REMOVAL The crest of the ilium is the most satisfactory donor area for nasal bone grafts. The ilium is trimmed

FIG 709 Roentgenogram showing bone graft consolidated with the nasal bones twenty-five years after transplantation.

with a wide osteotome, forming a dome shaped crest which is then removed as a transplant to form the nasal dorsum (Fig 710A B) The sharp edges of the borders of the crest are resected and preserved for they may be used as columellar struts. The periosteum and the soft tissues covering the crest of the ilium are approximated no drainage is required after thorough hemostasis.

The transplant is partly shaped before removing it from the iliac crest by trimming the convex surface of the crest.

BONE GRAFT IMPLANTATION Nasal implants over the bony dorsum can be introduced through an intercartilaginous incision at the lower border of the lateral cartilage, similar to the incision used for exposing the nasal framework in the typical corrective plastic procedure. The intercartilaginous incision may not allow for adequate exposure when the implant requires extension over the cartilaginous vault and should be employed for small grafts only The incision for exposure should always be distal to the area of the dorsum which requires the bone graft. A cartilage splitting incision through the lateral crus or a rim incision at the free margin of the alar cartilage may be indicated.

Other types of incisions may be required. The bone graft should be placed to raise the tip for example to correct flatness which involves the tip of the nose, in addition to filling a depression along the dorsum. Maintenance of the raised appearance of the nasal tip requires additional bone, placed in the columella to function as a strut adequate exposure of the columella is therefore necessary A mid-columellar vertical incision (Fig 711B) offers a good line of approach to the dorsum of the nose, passing between the medial crura and beneath the junction of the domes where the alar cartilages meet to form the nasal tip Such an incision also permits the placing of the columellar strut the vertical mid columellar incision has proved superior to the horizontally placed butterfly or bird in flight incision (Fig 711A) and leaves a barely discernible scar because closure without tension is possible after raising the tip Considerable difficulty may be encountered in suturing the edges of the butterfly type of incision at the tip under tension. Another incision extends along the free margin of

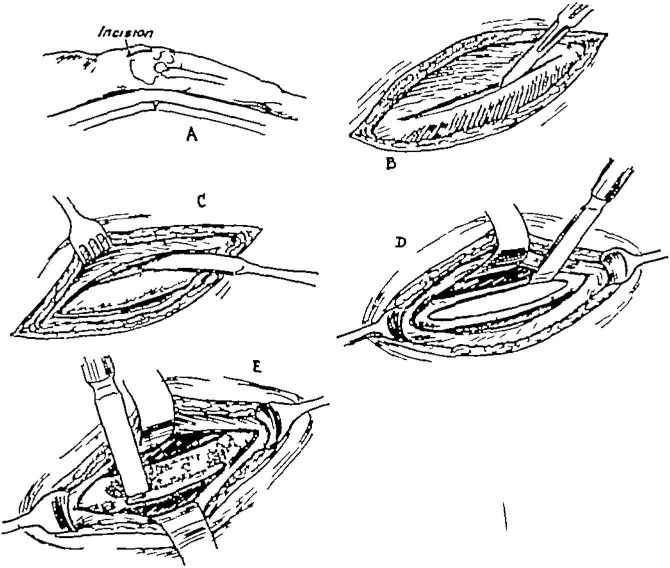


Fig 710. Iliac bone removal for saddle-nose deformity

A. Position of skin incision lateral to iliac crest
B. Incision through the periosteum over the crest.
C. Raising the periosteum and exposing the crest.
D. Osteotome cutting the bone graft.
E. Resection of a piece of cortical bone for the columellar strut when required.

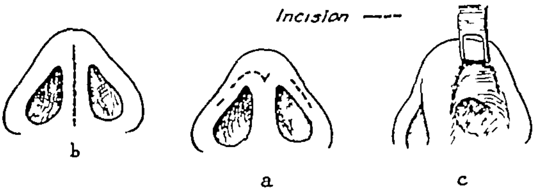


Fig 711 Three types of incision for implantation of bone graft to the dorsum of the nose

the lateral crus of the alar cartilage around the point of junction of the lateral and medial crura and downward along the free margin of the medial crus (Fig 711C D) Although the mid-columellar incision leaves only a slightly noticeable scar the marginal incision scar is completely hidden if carefully approximated.

The medial crura are separated from each other with a pair of small blunt tipped scissors the cleavage plane is extended upward over the lateral cartilages and the bony dorsum (Fig 712C) It is usually not necessary to separate the medial crura where they meet at the tip of the nose When a large graft is required, the separation of the medial crura must include the area of the tip to allow for introduction of the implant. The tip cartilages can be approximated with a mattress suture of 4-0 chromic cat gut after placing the bone graft (Holmes, 1954) Subperiosteal contact between the graft and the nasal bones is essential.

When bone implants of moderate size are used the periosteum is raised along the lower border of the nasal bones, and

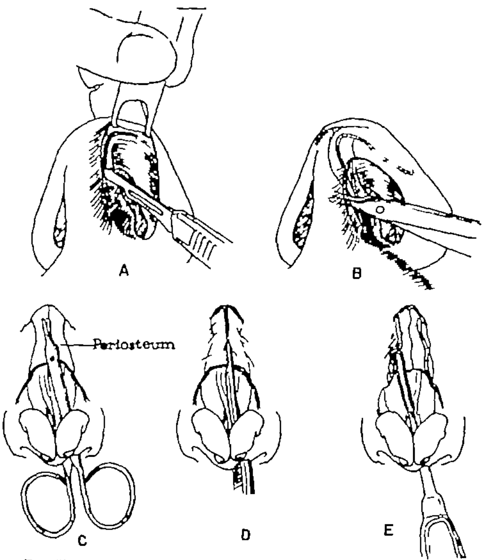


FIG 712. Technique of bone grafting for contour restoration of the nose
A. Marginal incision for introduction of the bone graft.
B. Small blunt-tipped scissors separating the medial crura, one from the other
C. Undermining by the scissors is extended over the lateral cartilage to the dorsum of the nose.
D An incision in the shape of an inverted T is made through the periosteum, covering the bony dorsum. A vertical incision and two horizontal incisions are made along the lower border of the nasal bones.
E. The periosteum is reflected, thus exposing the bony dorsum.

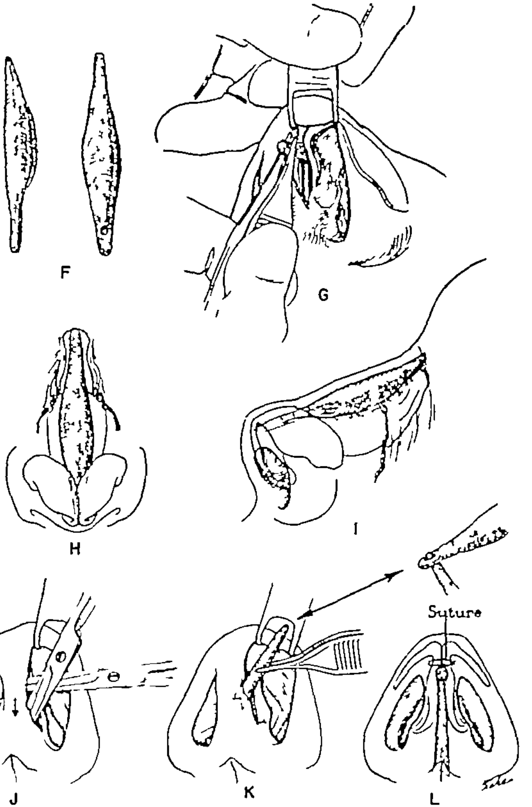


Fig. 713 Technique of bone grafting for contour restoration of the nose (*Continued*)

F The bone graft is suitably shaped.

G Introduction of the bone graft along the dorsum of the nose. The lower end of the bone graft is placed beneath the junction of the medial crura of the alar cartilages at the tip of the nose.

H Position of the bone graft along the dorsum of the nose.

I *Preparation of a pocket for the strut in the columella.*

J Placing the bony strut in the columella.

K and L Final positions of the bone graft and the supporting strut. The strut rests on the nasal spine. The medial crura of the alar cartilages are held in apposition by a suture in order to prevent their separation from the pressure of the bone graft. The position of the graft below the tip maintains the protrusion of the tip.

(Figs. 712 and 713 from J. M. Converse: Plast. & Reconstruct. Surg. 14:337, 1954.)

the graft is placed beneath the periosteum In larger implants, a vertical incision is made through the periosteum in the mid line horizontal lines of incision through the periosteum are also made immediately above the lower border of the nasal bones and the periosteum is reflected laterally on each side (Fig 712D E) Bony irregularities are smoothed with a rasp In malunited comminuted fractures it is particularly nec essary to denude the bone of scar tissue in order to assure contact between the graft and the bone. The bone graft from the ilium is shaped and introduced (Fig 713H I) and should rest in position without rock ing When a graft is placed beneath the tip cartilages there is a tendency for the implant to be pulled downward by the tip thus causing a protrusion of the upper end of the implant at the root of the nose. This rocking is prevented by a columellar strut which maintains the position of the lower end of the implant. An additional technique to prevent rocking consists of creating a niche at the nasofrontal angle (Campbell 1957) A straight osteotome is malleted into the solid bone in this area and levered upward. The upper end of the bone graft is then anchored under this small flange of bone. The columella is tunneled downward toward the nasal spine and a bony strut is placed over the nasal spine after the latter has been stripped of periosteum (Fig 713J K L) It is usually necessary to excise a small V-shaped segment of bone from the lower end of the strut to fit it over the nasal spine this procedure controls the tendency of the strut to shift. The junction between the strut and the dorsal graft is best achieved by the "tent pole technique which prevents loss of con tact between the two pieces of bone. A small hole is drilled through the anterior end of the bone graft and the pointed end of the strut is introduced into the hole. After the desired degree of elevation of the tip is achieved two shoulders are cut on the strut to prevent the pointed end of the strut from extending too far through the hole thus lowering the level of the dorsal bone graft. The strut cannot be used when the columella is scarred and deficient the bone graft can be wired to the nasal bones with stainless steel wire in such conditions.

In marked depression of the tip as in traumatic deformities with loss of septal support and in congenital deformities such as the bilateral cleft lip where the columella is short, raising the tip by means of the bone graft and the columellar strut is of value in maintaining the elevated position of the tip after elongation of the columella (see Figs. 667 and 668)

The dorsal graft is usually composed of a single piece of cancellous bone with a small amount of cortex to supply rigidity When the overlying soft tissues do not per mit placing a single transplant of adequate size a smaller piece of bone is introduced and chips of cancellous bone are added between the transplant and the underlying nasal bones until the desired degree of pro trusion is obtained. Undue pressure must not be exerted upon the covering nasal skin blanching of the skin is a sign of pres sure requiring a diminution in the size of the graft. Progressive increase in the size of the implant by staged procedures is pref erable to the possibility of pressure necrosis of the skin. Figures 714 and 715 show the result of bone grafts employed to correct depression of the nasal dorsum.

Tibial grafts were used quite extensively formerly but have been mostly discontinued because of possible fracture due to weak ening of the bone. In children however a small sliver of tibial bone from the medial aspect of the superior anterior border can be used advantagously and is preferable because the iliac crest of the child is largely cartilaginous.

Bone grafting may be combined with cor rective nasal plastic procedures following excision of a dorsal hump or osteotomy of the lateral walls of the nose, and nasal tip surgery

A B

C D

Fig. 714

A and B. Preoperative.

C and D. Postoperative photographs of patient following iliac bone graft repair of saddle deformity of the nose.

Costal Cartilage Grafts

Costal cartilage is used occasionally in repair of saddle deformities. The operative technique for exposing the costal cartilage is described in Figures 474 and 475, Chapter 19. Cartilage grafts are implanted in a manner similar to that employed for bone grafts; a columellar strut is employed when indicated.

To offset the curling effect of costal

FIG 715. Saddle-nose deformity (A and C) corrected by iliac bone graft (B and D) (Patient of Dr Ross M. Campbell)

cartilage, the common cartilage at the junction of the eighth, ninth, and tenth ribs is exposed, the perichondrium is elevated and two or three slivers of very thin cartilage are removed with a gouge. When these are trimmed and inserted one above the other the tendency for curling is lessened (Kazanjian)

Complications Following Corrective Nasal Plastic Surgery

Infection following hematoma is usually due to inadequate splinting of the operated nose Inadequate narrowing of the nose results from incomplete osteotomy or incomplete in fracture of the lateral wall An uncorrected deviated septum which causes pressure against the lateral nasal wall, is another cause of inadequate narrowing of the nose. After the lateral wall has been moved medially the spring-like pressure of the septum returns it to its original position. It may be assumed that the displacement is caused by a deviated septum when widening recurs after the in fracture.

Inadequate narrowing may also be due to undue thickness of the cartilaginous or bony septum (Fig 716*A*) The septum is trimmed in such cases to diminish the thickness (Fig 716*B*) The dorsal edge of the septum occasionally projects between the lateral walls, preventing their juxtaposition this condition may in turn result in an objectionable sharp central ridge on the bony dorsum

A complication after removing the hump is the interposition of mucous membrane between the cut segments along the dorsum Direct observation by means of an angular retractor and proper illumination reveals excess mucous membrane which should be trimmed prior to in-fracture of the lateral walls

The nose with convex and irregular bony walls following malunited fracture presents another type of deformity in which adequate narrowing of the dorsum after osteotomy is not possible The lateral walls must be comminuted in such cases to permit realignment. Comminution of the bone is accomplished by tapping the lateral wall

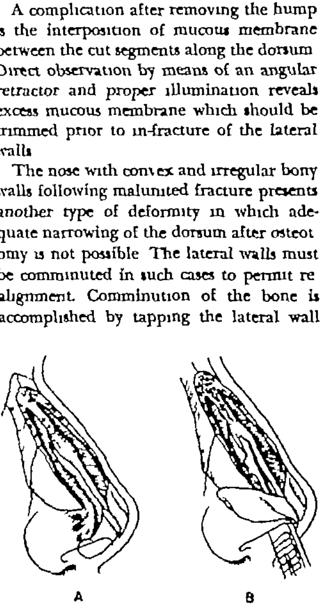


FIG 716 A thick septum as a cause for inadequate narrowing of the nose following osteotomy of the lateral nasal walls.

A. A frequent site of thickening of the dorsal edge of the septum is at the junction of the bony septum.

B. Illustrates technique of thinning the dorsal border of the septal cartilage by paring it with a knife.

with a mallet the skin having been protected by a gauze pad

Irregularities under the surface of the skin are due to roughening of the modified nasal framework caused by small protruding edges of cartilage or loose pieces of bone *which may produce exostoses.*

Complications, following correction of the tip of the nose are usually caused by failure to achieve satisfactory shaping of the nasal tip by inappropriate inadequate or excessive surgical procedures Slight irregularities may be corrected by small cartilage grafts or by trimming protruding edges of cartilage Secondary procedures should be instituted after the edema has *subsided and the tissues have softened* not earlier than four months following the primary operation The Safian or eversion techniques have provided satisfactory methods of approach for these operations. Inadequate contraction of the soft tissues and the pinched tip deformity are complications requiring special consideration

INADEQUATE CONTRACTION OF THE SOFT TISSUES OVER THE MODIFIED FRAMEWORK Contraction of the soft tissues may extend *over a period of six months or as much as a* year following corrective procedures Because the soft tissues fail to adopt themselves to the underlying profile line a convexity of the supratip area occurs which impairs an otherwise satisfactory result. The convexity in the supratip area is usually temporary in young individuals, due to soft tissue excess alone for the skin is rich in elastic fibers and contraction occurs progressively in older individuals, such *progressive contraction may not occur* The age of the individual is therefore a consideration when planning reduction in the size of a very large nose

Swelling in the supratip area may also be due to an excess of localized subcutaneous fat and muscular tissue which necessitates subsequent removal The eversion technique gives adequate exposure for the procedure Removal of the subcutaneous tissue is accomplished with scissors, and care should be exercised while dissecting the subcutaneous tissue to avoid skin necrosis.

Thickening and stiffening over the tip may be due to large sebaceous and sweat glands in the region Seborrheic skin *does not contract and is unfavorable for satis*factory modification of the tip.

Convexity in the supratip area is often the result of inadequate trimming of the septal angle it may also be due to excessive removal of septal cartilage and the formation of a pocket between the septal angle and the alar cartilage (see Fig 619)

THE PINCHED TIP DEFORMITY Excessive removal of cartilage from the dome results in a pointed tip a *difficult condition to cor*rect A pinched deformity with stenosis of the nasal airway results, particularly if an excess of vestibular lining has also been removed when excessive cartilage has been resected from the lateral crus of the alar and the lateral cartilages (Fig 717)

The pinched nose with vestibular stenosis presents a dual problem the deficiency of the lining which causes an inward pull upon the external nasal structures and the *cartilagenous nasal wall requiring support.* Such cases have been successfully treated by the following procedure Intranasal scar tissue is removed and cicatricial bands are eliminated by a z plasty procedure The remaining intranasal raw area is then covered by means of full thickness skin grafts from the upper eyelids, the posterior aspect of the auricle or inner aspect of the arm or split thickness of oral mucosa (see Fig 161 Chapter 18) The technique of skin grafting in*side the nasal cavity is described* later in this chapter (see Fig 719) Impressions of the nasal cavity are made with dental compound A mold of compound is made for each vestibule and is duplicated One of these serves to carry the skin graft which is placed over the mold, raw surface outward The alternate mold is employed in the construction of a thin acrylic prosthesis. The dental compound mold is removed after a

period of four or five days and is replaced by the prepared acrylic prosthesis. These molds can be shell like in thickness and are inconspicuous when worn inside the nose they are designed to fit into the recess of the vestibule above and behind the internal narial fold below The prostheses should be worn for a long period of time because of the probability of eventual contraction of the intranasal skin graft when the cartilage deficiency is extensive they should be worn permanently Figure 717 illustrates a case in which this type of treatment was employed to eradicate a deformity produced by excessive removal of cartilage and vestibular skin

Fig 717 The pinched tip due to excessive removal of alar cartilage and vestibular lining

A and C Typical appearance of pinched tip following an operation by an unqualified practitioner Note also the inadequate osteotomy and profile line correction, the retraction of the columella and drooping of the tip.

B and D Correction obtained by secondary osteotomy and modification of the profile line autogenous septal cartilage graft in the columella. The deficient nasal lining was restored and small thin acrylic molds employed for support.

E. Typical pinched tip.

F Result obtained. Note intravestibular molds visible in photograph. These acrylic molds were designed and fitted by Dr Harry H Shapiro

DEFORMITIES OF THE INNER LINING OF THE NOSE

Contraction following loss of the inner lining of the nose through injury or infection results in stenosis or atresia of the nasal vestibule or fossa The condition is more complicated when the supporting framework of the nose has been fractured or partially destroyed. The external contour of the nose is not usually altered by adhesions of moderate degree within the nose extensive loss of nasal lining, however especially when complicated by infection may alter the contour of the lower part of the nose

The surgical treatment of nasal stenosis depends upon the extent and location of the obstruction the condition of the surrounding lining and the degree of external deformity

Z flaps for Linear Scar Contracture

When the loss of vestibular skin is not extensive and the air passage is obstructed by contraction from the linear ring of scar tissue the repair is accomplished by Z or trap-door incisions This procedure is indicated when the web is limited to the vestibule where incisions for the transposition of flaps are feasible

The two layers of the ring of contracted tissue are separated through an incision along the borders of the constriction A vertical incision is made through the anterior skin lining beginning at the roof of the nostril close to the septum and down to the edge of the ring (Fig 718*A*) Another flap is formed on the posterior lining of the stenosing ring by an incision close to the lateral wall (Fig 718*B* *C*) The contracture is relieved by transposing a triangular shaped flap from each side of the constricted ring (Fig 718*D* *E*) A petrolatum gauze packing is maintained in the vestibule for a few days

with a mallet the skin having been protected by a gauze pad.

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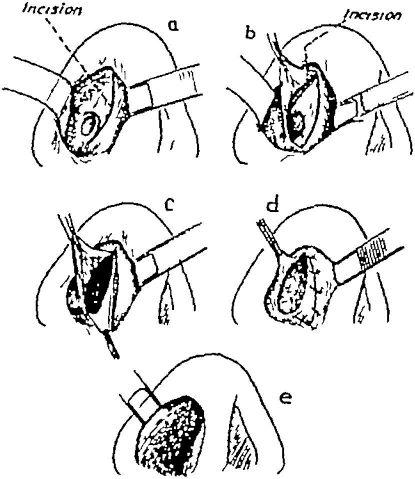

FIG 718. Correction of nasal stenosis

A. Incision along the septum is extended laterally around the opening of the stenosed area.
B. The anterior flap is raised, exposing the posterior flap.
C. The nasal passage is exposed and the anterior and posterior flaps are retracted previous to transposition.
D. The posterior flap covers the raw area over the septum.
E. The anterior flap covers the raw area over the lateral wall

Skin Grafting within the Nose

If the obstruction consists of more than a web a new lining is provided by skin grafting The scars are excised and the lateral wall is freed from the septum A split thickness skin graft preferably from the inner aspect of the arm a full thickness graft from the upper eyelid or a graft of oral mucosa may be employed Provision is also made for immobilization of the skin graft within the nose A temporary mold of dental compound serves as the carrier for the graft The compound is softened and molded into an oval-shaped cone and is cooled and hardened. The outer layer is covered with petrolatum and flamed the inner part of the compound is not softened The cone is then reintroduced into the nostril, molded against the lateral walls and removed A small amount of dermatome cement is dabbed on the mold and the graft is wrapped around it, raw surface outward it is then inserted in the nostril (Fig 719)

The mold is retained for four to five days The original compound mold is duplicated in acrylic When the temporary compound mold is removed, the hollowed acrylic mold is introduced into the nostril Shrinkage and constriction of the graft is thus minimized the resiliency of the septum and nasal cartilages prevent recurrence of stenosis The postoperative mold is retained for a number of months.

When stenosis is the result of excessive

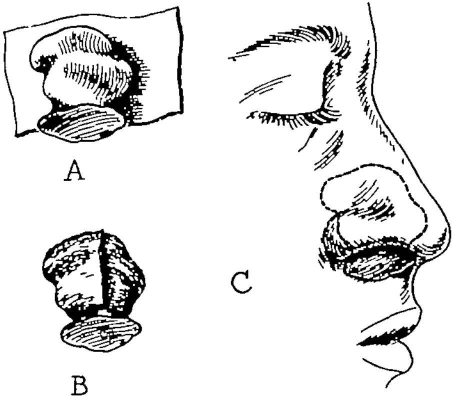

FIG 719 Epithelial inlay technique for correcting stenosis of the nasal vestibule

A. Dental compound mold made from impression of the nasal vestibule after release of scar contracture. A skin graft is wrapped around the mold raw surface outward

B. Mold covered by the skin graft.

C. Drawing showing mold in position in the nose.

removal of lateral and alar cartilage as well as nasal lining (Fig 717) the prosthesis supports the deficient cartilaginous structures and is retained permanently to assure patency of the airway

Mucosal grafts removed from the oral mucous membrane may also be employed for intranasal grafts Mucosa does not tend to crust and to produce a fetid odor

Nasomaxillary Epithelial Inlay (Gillies, 1923)

A marked deformity results when the nasal bones and the middle portion of the maxilla have been destroyed or are undeveloped due to trauma in childhood The condition has been referred to as "dish face" The nasal cavity is lined to permit insertion of a prosthesis, which is designed to support the soft tissue of the nose and to replace missing maxillary bone and teeth.

The nasal epithelial inlay technique is illustrated in Figure 720 A typical example of a case requiring such reconstruction is shown in Figure 721 This patient was injured by a bomb fragment which entered the face in front of the left ear The missile traversed the upper part of the maxillary sinus, penetrated the lateral wall of the nose, continued across the nasal cavity and made its exit on the right side of the nose Most of the supporting nasal structures were destroyed the skin however except for the perforation remained intact.

The operative procedure follows under intratracheal anesthesia, an incision is made in the upper buccal sulcus (Fig 720*A*) the nasal fossa is entered from within the sulcus (Fig 720*B*) and the external nasal structures are freed of adhesions an extensive raw area results. The nasal spine is removed (Fig 720*C*) A compound mold is then constructed to fit a pyramidal-shaped cavity (Fig 720*D*) with the apex pointing upward in order that the mold can be inserted and removed easily The mold is

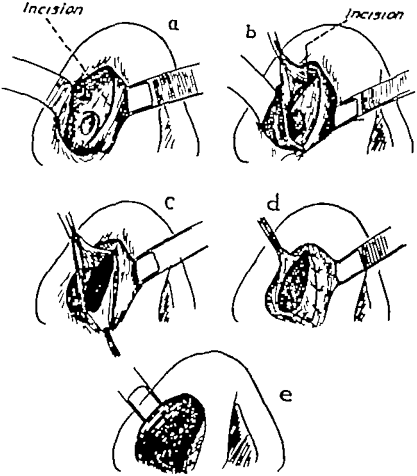

FIG 718. Correction of nasal stenosis

A. Incision along the septum is extended laterally around the opening of the stenosed area.
B. The anterior flap is raised, exposing the posterior flap.
C. The nasal passage is exposed and the anterior and posterior flaps are retracted previous to transposition.
D The posterior flap covers the raw area over the septum
E. The anterior flap covers the raw area over the lateral wall

Skin Grafting within the Nose

If the obstruction consists of more than a web a new lining is provided by skin grafting The scars are excised and the lateral wall is freed from the septum. A split thickness skin graft, preferably from the inner aspect of the arm a full thickness graft from the upper eyelid or a graft of oral mucosa may be employed. Provision is also made for immobilization of the skin graft within the nose A temporary mold of dental compound serves as the carrier for the graft The compound is softened and molded into an oval-shaped cone and is cooled and hardened The outer layer is covered with petrolatum and flamed the inner part of the compound is not softened. The cone is then reintroduced into the nostril, molded against the lateral walls and removed A small amount of dermatome cement is dabbed on the mold and the graft is wrapped around it raw surface outward it is then inserted in the nostril (Fig 719).

The mold is retained for four to five days The original compound mold is duplicated in acrylic When the temporary compound mold is removed the hollowed acrylic mold is introduced into the nostril Shrinkage and constriction of the graft is thus minimized the resiliency of the septum and nasal cartilages prevent recurrence of stenosis. The postoperative mold is retained for a number of months

When stenosis is the result of excessive

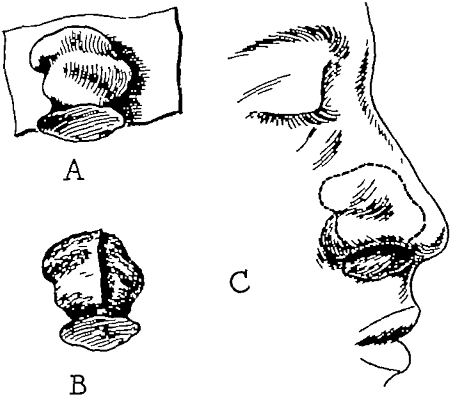

FIG 719 Epithelial inlay technique for correcting stenosis of the nasal vestibule

A. Dental compound mold made from impression of the nasal vestibule after release of scar contracture. A skin graft is wrapped around the mold, raw surface outward.

B. Mold covered by the skin graft.

C. Drawing showing mold in position in the nose.

removal of lateral and alar cartilage as well as nasal lining (Fig 717) the prosthesis supports the deficient cartilaginous structures and is retained permanently to assure patency of the airway

Mucosal grafts removed from the oral mucous membrane may also be employed for intranasal grafts Mucosa does not tend to crust and to produce a fetid odor

Nasomaxillary Epithelial Inlay (Gillies, 1923)

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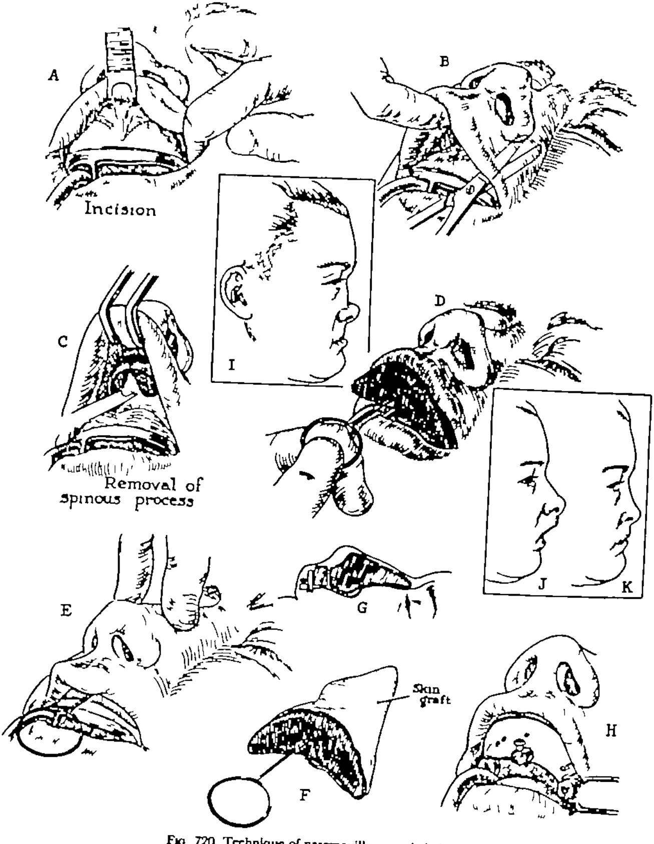

Fig 720. Technique of nasomaxillary epithelial inlay

A. Outline of incision
B The nasal cavity is entered through the mouth.
C. The nasal spine is resected.
D A dental compound mold is fitted to the cavity
E. The softened compound is fitted by external digital pressure
F The mold is covered by a thin skin graft, raw surface outward.
G The mold carrying the skin graft is placed inside the nasomaxillary cavity It is held in position by a splint anchored to the upper molar teeth
H Position of the mold in the nasal cavity
I J and K Appearance of the patient before during and after the epithelial inlay procedure

FIG 721 Contour restoration of the nasomaxillary area by epithelial inlay

A. Photograph showing deformity of the nasomaxillary area due to bomb injury having resulted in bone loss of the superior alveolar process and adjacent maxillary bone and in destruction of the nasal septum and of nasal lining Note the deepening of the nasolabial folds due to retrusion of the framework of the middle portion of the face. (From J M. Converse, Arch. Ophth 31 323 1944 A and B)

B. Result obtained by nasomaxillary epithelial inlay Note change of contour of the nose, the normal appearance of the nasolabial folds and of the upper lip

C. Profile view of patient before operation.

D Restoration of contour obtained by epithelial inlay

E. Photograph showing patient introducing the prosthesis.

F Photograph of the appliance. The denture is prolonged upward by an extension forming the nasal support. Holes are drilled in the appliance to restore the nasal airways.

duplicated to construct a permanent acrylic prosthesis. A split thickness graft from the inner aspect of the arm, spread over the mold raw surface outward is inserted into the nasal cavity (Fig 720*E* to *G*) The tissues should be distended by the compound mold in order to insure close coaptation of the graft around the soft tissues and to counteract possible subsequent contraction of the graft. The mold is removed after two weeks, and the cavity examined and cleansed At intervals during subsequent weeks the size of the mold is diminished After a period of six to eight weeks, a permanent acrylic support attached to an upper denture is employed to maintain the normal contour of the nose (Figs. 721 and 722)

The nasomaxillary epithelial inlay technique, originally developed by Gillies for the treatment of the syphilitic nose deformity is indicated occasionally in the traumatic nasomaxillary deformity particularly in the edentulous patient It has been largely superseded by employing skin flaps to replace the deficient nasal lining

Nasolabial Flaps for Relining the Nose

A method for repairing the collapsed nose, due to loss of the nasal lining, consists of restoring the inner lining by turning two flaps of skin inward from the nasolabial region (Kazanjian 1937) An incision is made around the alar margins of both sides extending to the base of the columella (Fig 723*A*) and the tip and alae of the nose are retracted upward. The skin is freed from fibrous adhesions and dissected freely over the entire nose including the region of the bony bridge A flap is prepared on each side by making a curved incision from the sides of the alae in a direction correspond

Fig 722 Correction of dish-face deformity by epithelial inlay

A. Photograph of patient who had sustained complex fractures of the bones of the middle portion of the face as a result of an automobile accident. Note the retrusion of the upper lip, shortening of the nose and backward displacement of the middle portion of the face The patient was unable to occlude the lips. Forty two unsuccessful operations had been performed during the preceding ten years

B. Result obtained by the nasomaxillary epithelial inlay technique illustrated in Figure 720 (Prosthesis made by Dr Andrew J Ackerman)

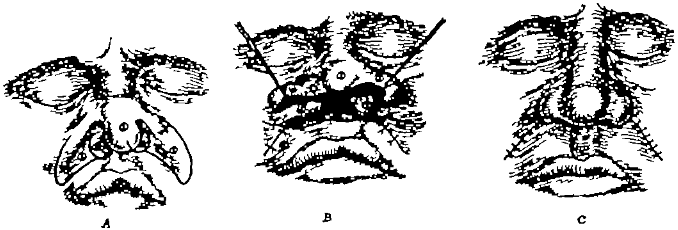

FIG 723 Restoration of nasal lining by nasolabial flaps

A. Outline of incisions for nasolabial flaps. Incisions are made around the base of the alae and the columella.

B. The alae and the nasal tip are retracted upward, the scarred tissue inside the nasal vestibule is resected and the nasolabial flaps turned up into the nasal cavity

C. In a second stage the nasolabial flaps are severed and the alae replaced The final suture lines are shown

(Figs. 723 and 724 from V H. Kazanjian, Tr Am. Acad. Ophth. and Otol., 42 338, 1937)

FIG 724

A and B. Photographs showing nasal deformity primarily due to loss of the lining of the nose. Note the marked retraction of the upper lip and shrinking of the lower half of the nose.

C and D Postoperative photographs. The supply of skin flaps from the nasolabial area according to the technique shown in Figure 723 was sufficient to give the nose a normal appearance.

ing with the nasolabial folds. These flaps are raised turned inward and sutured in place to form a new lining for the nasal cavity No attempt is made to suture the base of the alae at this time (Fig 723*B*) The pedicle of the flaps forming the inner lining of the nose are sectioned two weeks later some of the excess tissue is excised, and the bases of the alae are replaced and sutured (Fig 725*C*) Figure 721 illustrates

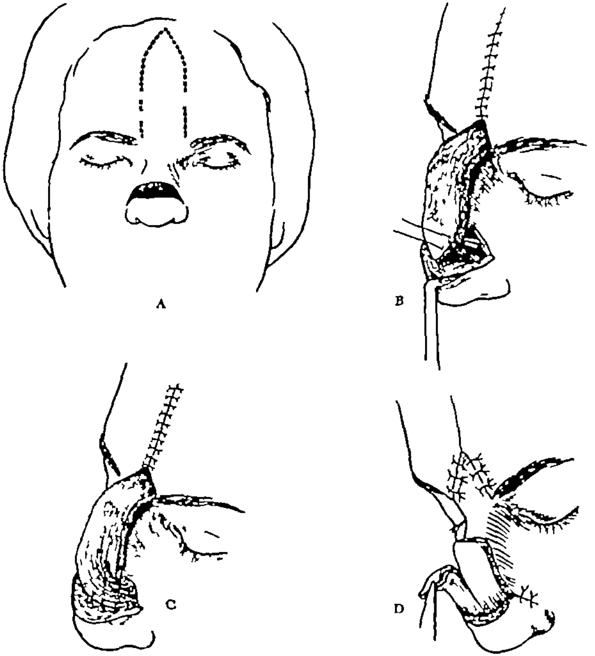

Fig 723. Restoration of nasal lining by median forehead flap

A A transverse incision is made above the tip of the nose and the nasal cavity is entered The incision releases the lower portion of the nose permitting it to resume its normal position.

B and C The nasal defect is repaired by median forehead flap turned down skin surface facing the nasal fossa The edges of the flap are sutured to the nasal lining The raw surface of the flap is covered by a split thickness skin graft

D At a later stage the pedicle of the flap is severed, the skin graft is removed, the flap is split and each half is introduced into the nasal fossa, thus supplying the defective nasal lining

Figs 725 to 727 from V H Kazanjian, Plast & Reconstruct Surg 3 517 1948)

e repair by this method of a deformity ue to loss of nasal lining

Median Forehead Flap for Relining the Nose

The technique of the median forehead p method for relining the nose is shown Figure 725 A patient in whom the tech que was employed is shown in Figures 6 and 727 The various stages of the op ation follow

1 A transverse incision is made above the tip of the nose and the nasal cavity is entered. The incision releases the lower portion of the nose permitting it to resume its normal position (Figs. 724*A* and 725*A*)

2 The defect caused by the incision is repaired by a median forehead flap which is turned down skin surface facing the nasal cavity (Fig 725*B*) The edges of the flap are sutured to the nasal lining (Fig 725*B* *C*)

3 The raw surface of the flap is covered by a split thickness skin graft serving as a temporary skin dressing (Fig 727*A*)

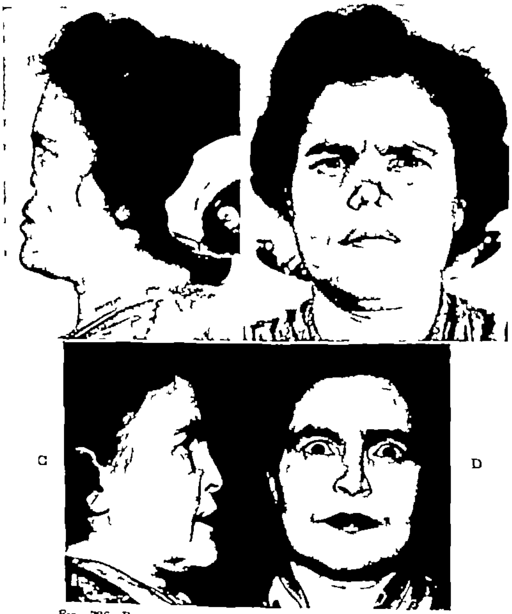

FIG. 726 Restoration of nasal lining by median forehead flap

A and B. Preoperative photographs, showing collapse of the lower half of the nose due to loss of cartilagi ous support and contraction of the nasal lining

C and D Result obtained by technique illustrated in Figure 725 and subsequent restoration of contour y an iliac bone graft.

A B

Fig 727 Restoration of nasal lining by median forehead flap

A Photograph showing the end of the forehead flap sutured to the edges of the inner lining of the nose as shown in Figure 725. The raw area on the flap is covered with a skin graft.

B Appearance after section of the pedicle and implantation of the forehead flap inside the nasal cavity restoring the deficient nasal lining as shown in Figure 725. (See final result, Fig 726 C and D.)

4 The pedicle of the flap is severed a few weeks later the temporary skin graft is removed, the flap is split and each half is introduced into the nasal cavity thus supplying the defective nasal lining (Fig 725D)

5 The covering skin is sutured (Fig 727B) In a further procedure the contour is improved by a supporting iliac bone graft (Fig 726B)

Another method for supplying an inner lining utilizing a median forehead flap is described later in the text (Kazanjian 1946) (see Fig 755)

FULL THICKNESS LOSS OF NASAL TISSUE

Defects which involve the full thickness of the nose may be relatively small involving the loss of the ala only a portion of the tip of the nose or if the defect is extensive the entire lower half of the nose Loss of the entire nose is unusual in traumatic injuries.

The reconstructive procedures required for full thickness defects of the nose include the restoration of an outer covering an inner lining and a supporting framework.

The development of plastic surgery is so intimately associated with that of reconstructive rhinoplasty that a summary of the history of the art of reconstructing the nose assists in understanding the development of newer techniques.

In ancient times amputation of the nose was considered a justifiable punishment for a variety of crimes ranging from robbery to adultery There were episodes in ancient India during which conquered peoples were marked by amputation of the nose "Baronio relates that in 1769 A.D the city of Kirtitoor in the island of Ceylon was besieged by the

Ghoorka King Pritwinarizan and that the city was taken by treason after a long resistance. The victor irritated by the resistance, ordered the death of the most illustrious citizens and the cutting of the nose and lips of all the inhabitants except those who knew how to play a wind instrument. The order was executed without pity for the vanquished and the victor to add a cruel irony to his barbarous resolve decided that the city would from thence on carry the name Nescatapor which means city of the cut noses (Blandin 1836)

Self-mutilation by cutting off the nose was also practiced by women who wished to protect their honor by disfiguring themselves According to Rousset as related by Nélaton and Ombrédanne (1904) this occurred during the Danish invasions of England and when the Saracens stormed Marseilles the mother-superior of a convent and forty nuns inflicted this disfigurement upon themselves

Even in modern times in certain regions of India and Pakistan avulsion of the nose by a sharp-cutting instrument is dealt out as punishment to adulterous wives (Blocksma and Innis 1955)

The Koomas of ancient India members of the caste of potters, had developed the art of reconstructing the destroyed nose by means of a forehead flap a method often referred to as the Indian method and described in the writings of Sushruta (*circa* 800 B C.)

In Europe during the fifteenth century Branca and his son developed a successful rhinoplasty technique as related by Ranzano in 1442. The elder Branca practiced the method of repair described by Sushruta Arabian scholars during the eighth century had made Arabic translations of the works of Sushruta Sicily was a center of Arabian Greek and Occidental learning in the eleventh and twelfth centuries such facts suggest that knowledge of the ancient Indian operation may have reached Branca (Gnudi and Webster 1950)

During the sixteenth century Tagliacozzi eminent anatomist and surgeon of Bologna was the first to practice the reconstruction of the nose by means of a direct delayed flap from the arm His skillful technique became known as the "Italian or Tagliacotian method and is described in detail in his book (1597)

Reconstructive rhinoplasty appears to have been neglected during the subsequent two centuries and even to have fallen into disrepute

Interest in the Indian rhinoplasty was revived through the case of an ox driver named Cowasjee who worked for the British Army in India the story was told in the "Hircarrha or gazette of Madras in 1793 This man was captured by Typo-Sahib who ordered that his nose be cut off to punish him for his treachery Cowasjee s nose was later restored by a forehead flap operation performed upon him by members of the initiated caste The publication of this case prompted English surgeons to attempt the operation and in 1816 Carpue published the successful results of the operation in two patients

Von Graefe performed a nasal reconstruction in Berlin in 1816 using the method of Tagliacozzi and the following year he employed the Indian method Reiner in Munich after a voyage to England where he had seen Carpue operate also employed the Indian method (Jobert, 1849) In France the Indian rhinoplastic operation was practiced by Delpech in Montpellier in 1823 and within the next few years by Lisfranc and Labat

Dieffenbach as early as 1829 began to classify procedures and improvements in the technique of forehead flap rhinoplasty and described them in 1845 his book is a major contribution to the literature of plastic surgery

One can but marvel at the dexterity of the surgeons and the courage of both patients and operators in those pioneer preaseptic days before the development of anesthesia

The following episode told by Labat (1833) is illustrative of an operation for reconstructing the nose performed by him in the year 1827 Labat's patient named Lannelongue was a former soldier in the Napoleonic armies he had lost his nose as a result of frost-bite during the retreat from Moscow The patient maintained by two aides, was seated in a chair " when I lengthened the incision toward the root of the nose the patient suffered such intense pain that he struggled from the firm grasp of the aides and ran toward the door to avoid submitting himself to the remainder of the surgical procedure At this moment Lannelongue presented a frightfult aspect his forehead showed a gaping wound, the edges of which were further retracted by pain his face neck and clothing were inundated with blood but the most horrible

B

A

C

D

F

FIG 728 Full thickness loss of tissue of the upper part of the nose

A and B Photograph showing loss of skin and skeletal framework of the upper portion of the nose caused by automobile accident Note the depression of the upper portion of the nose and the perforation into the nasal cavity *Additional skin covering is required in order to provide sufficient covering for a bone graft* and also closure of the full thickness defect

C A median forehead flap has been brought down over the upper portion of the nose The forehead defect has been closed by direct approximation

D and F Result obtained after bone grafting

sight of all was the flap of palpitating flesh which flopped over first one cheek and then the other with every movement he made Judging that my exhortations would be useless because persuasion could no longer have any effect on the mind of Lannelongue, exalted by pain I ran after him and locked the door of the apartment putting the key in my pocket In the authoritative tone required by the peculiar position in which I found myself I ordered him to return to the place I had assigned to him for the operation under the threat of the use of force Lannelongue realizing that further resistance was useless, sat down on the chair and withstood the remainder of the operation without even being required to be held by the aides.

Full Thickness Tissue Loss of the Upper Part of the Nose

Small defects near the root of the nose with perforation into the nasal cavity have resulted from crash injuries in automobile accidents in which the patient suffered a compound comminuted fracture of the bones of the middle portion of the face. An inner lining is unnecessary when the perforation is very small A flap from the median section of the forehead is usually brought down to cover the external defect (Fig 728) In larger perforations the skin

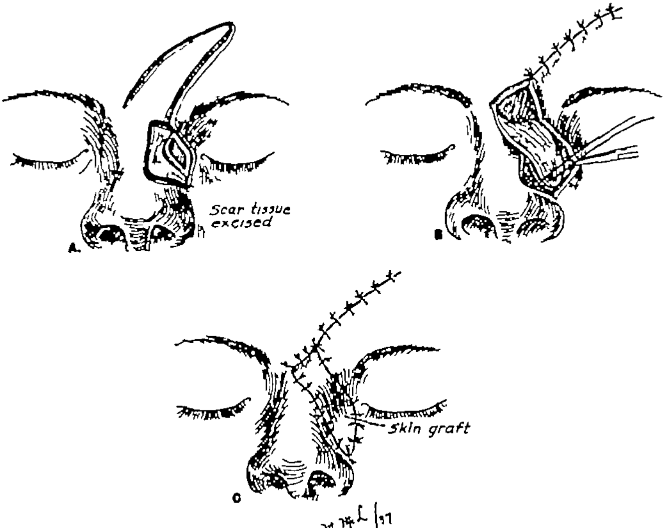

Fig 729 Reconstruction of full thickness loss of the upper part of the nose
A. Outline of incisions for forehead flap and for scar excision.
B. Forehead flap turned down into defect forming the inner lining of the defect.
C. A full thickness retroauricular skin graft is placed over the forehead flap constituting the covering of the defect.

surrounding the opening is raised and turned into the defect to form the inner lining the outer covering is borrowed from a more distant area preferably the forehead

When inverted local flaps cannot be employed a skin flap provided with a lining can be used in a preliminary step to cover the defect A full thickness skin graft from the retroauricular region or from the inner aspect of the arm is used for this purpose

A preferable method for closing a full thickness loss of nasal tissue is the use of a forehead flap to form a stable inner lining The flap is brought down the skin surface toward the nasal cavity and its edges are sutured to the lining of the nose A full thickness skin graft taken from the retroauricular region is sutured over the external raw area of the flap (Fig 729) The pedicle of the forehead flap is sectioned and the upper margin of the perforation is closed at a later period

A tubed pedicled flap from a more distant area usually supplies sufficient tissue to form an inner lining as well as an outer covering Such flaps however should be used only when the defect requires a large amount of tissue

Full Thickness Tissue Loss of the Lower Part of the Nose

Such loss includes a part or entire ala of the nose the tip including the columella or the entire lower half of the nose

Reconstruction with Adjacent Tissue

Utilization of the border of the defect to form the alar rim is a good procedure in suitable cases if an adequate nasal lining is provided In the defect shown in Figure 730 the vestibule is narrowed due to scarring of the lining and the border of the defective ala is pulled upward by dense scar tissue. After excision of the scar tissue two flaps from the upper and lower remaining parts of the nostril are brought together to form

A B

Fig 730. Reconstruction of ala ... tissue

A Photograph showing ... ht nostril with ... e

B. Photograph following ... rim by tech. ... in Figure 731

(Figs 730 to 733 from ... ian, Tr Am. ... and Otol 42 338 1937)

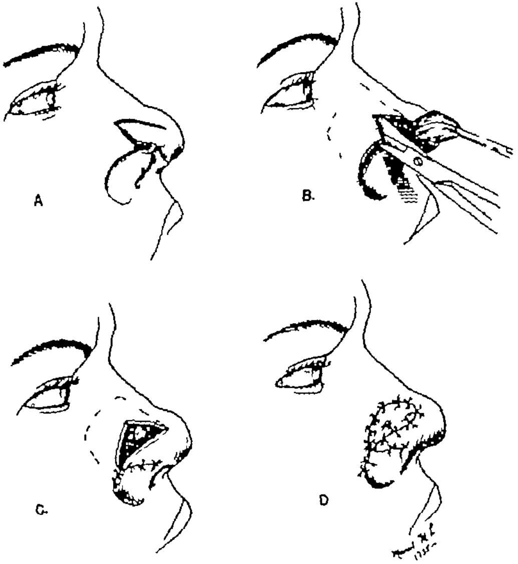

Fig 731 Reconstruction of ala with adjacent tissue

A. The scar is excised. The line of incision of the lower part follows the curve of the ala while the one above is toward the tip of the nose

B. The mucosal lining of the inner wall is then freely undermined and cut through above the level of the nasal bones.

C. It is possible to bring down the distorted parts of the nostril to repair the defect.

D The triangular skin defect above is covered with a retroauricular skin graft. A mold of dental compound is fitted to the nostril and an external pressure bandage is applied.

the lower border of the ala (Fig 731*B* *C*) In outlining these flaps, the incision is made through the skin only The deficiency in the nasal lining which remains is remedied by the following procedure (Kazanjian 1937) The lining of the lateral wall of the nose being continuous with the flaps is separated from the overlying lateral cartilage by subperichondrial dissection and from the undersurface of the nasal bones and frontal process of the maxilla by careful subperiosteal elevation (Fig 731*B*) The mucoperiosteum is then incised at as high a level as possible two vertical incisions and one horizontal incision outline a flap of mucoperiosteum that may be mobilized downward. The undermined flap is brought down with the skin flaps of the ala to supply sufficient inner lining. The final step consists of transplanting a full thickness skin graft from the retroauricular region to repair the skin defect above the alar rim (Fig 731*D*)

A similar simplified technique may be employed in a clean cut alar defect with smooth

A Fig 732 B

A. A clean-cut alar defect with smooth margins.
B Photograph of patient following repair by procedure described in Figure 733

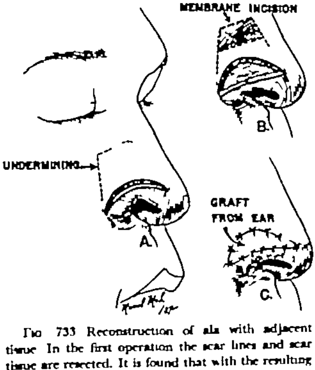

Fig 733 Reconstruction of ala with adjacent tissue In the first operation the scar lines and scar tissue are resected. It is found that with the resulting gaping of the wound the lower border of the defect falls near the proper border of the original nostril The mucosa is incised high up under the nasal bone and with a slight amount of undermining it is possible to lower the border further A full thickness retroauricular graft of skin is used to cover the oval skin defect.

margins and stenosis of the vestibule (Fig 732) A curved incision through he skin only is made approximately 0 d the margin of the defect (Fi e

skin of the edge of the defect is rolled downward to form the new alar border (Fig 733). The deficiency of the nasal lining tends to retain the alar border in its upward retracted position and the mucoperiosteum is dissected and elevated from under the nasal bone to outline a flap as previously described (Fig 733*B*) The mucosal flap is then brought downward thus relieving the deficiency of the nasal lining

In defects involving the lateral portion of the ala we have obtained good results by applying the principle outlined above of releasing the deficient inner lining by the mobilization of mucoperiosteum from the undersurface of the nasal bones (Fig 731) and by either of the two procedures (Figs 735 and 736) attributed to Denonvilliers (Verneuil 1877)

Reconstruction by the Septal Flap Method

This technique employed by de Quervain (1902) for defects of the lateral wall of the nose was adapted by Kazanjian (1937) for deformities which involve alar losses of moderate size The procedure is accomplished in three stages t stage consists of raising a rectangu flap through the entire thickness um at the level of the defect (Fi the base of the pedicle

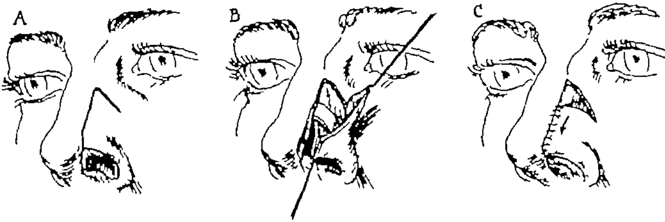

FIG 734 Downward mobilization of the cartilaginous lateral wall of the nose to repair an alar defect.

A. Outline of skin incision.

B. The mucous membrane is mobilized from the under-surface of the nasal bones to furnish a lining

C. Skin graft may be placed in the defect overlying the bony framework of the nose.

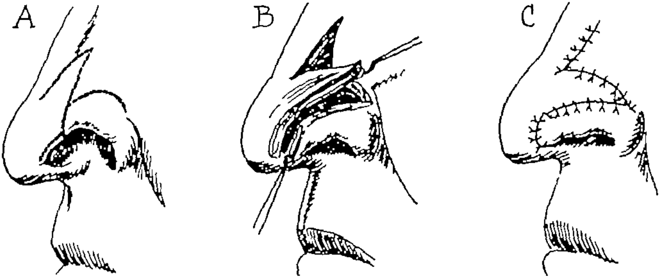

FIG 735 Local flaps to lower the border of the defect for the repair of defects of the ala (after Devonvilliers)

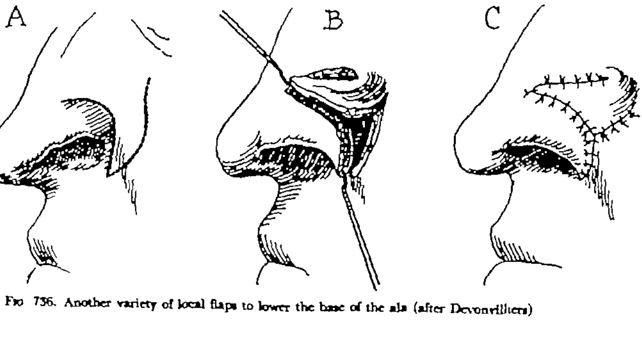

FIG 736. Another variety of local flaps to lower the base of the ala (after Devonvilliers)

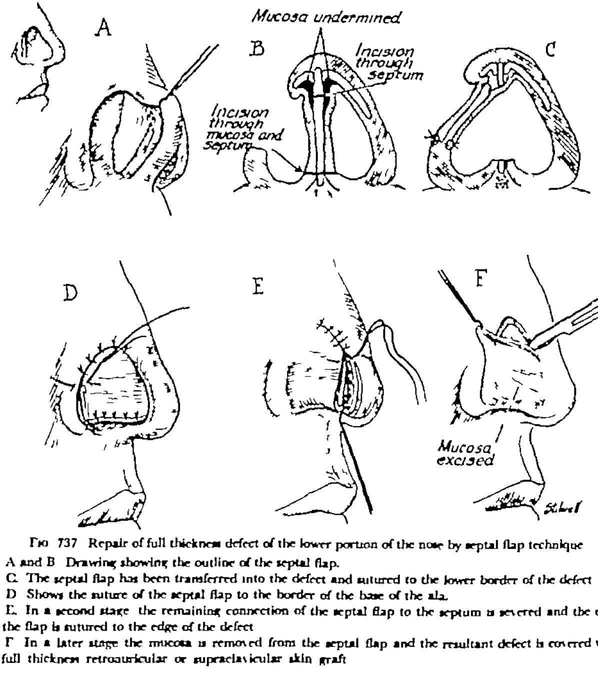

FIG 737 Repair of full thickness defect of the lower portion of the nose by septal flap technique

A and B Drawing showing the outline of the septal flap.

C The septal flap has been transferred into the defect and sutured to the lower border of the defect

D Shows the suture of the septal flap to the border of the base of the ala.

E In a second stage the remaining connection of the septal flap to the septum is severed and the edge of the flap is sutured to the edge of the defect

F In a later stage the mucosa is removed from the septal flap and the resultant defect is covered with a full thickness retroauricular or supraclavicular skin graft

is above The flap of cartilage, covered on both sides by mucoperichondrium is sutured to the borders of the alar defect and is supported by a mold of dental compound or by nasal packing (Fig 737C D) The remaining attachment of the septal flap to the septum is separated in the second stage this border is sutured to the edge of the defect along the bridge of the nose (Fig 737E) The exposed mucosa of the flap is dissected from the perichondrium removed in the third stage and replaced by a skin graft or flap placed directly over the perichondrium of the cartilage (Fig 737F) The septal flap should be designed in such a manner that sufficient septal cartilage remains along the dorsum of the nose to provide support The result of this procedure is quite satisfactory as the border of the reconstructed ala is suitable in thickness and harmonizes with the unaffected ala The septal flap technique may also be employed for larger defects of the side of the nose a forehead flap provides the outer covering (Fig 738)

A  B

Fig 738 Reconstruction of large defect of the side of the nose by septal flap method
A. A septal flap was used to form the framework as well as the inner lining of the side of the nose.
B A median forehead flap supplied the outer covering of the side of the nose.

Reconstruction with a Nasolabial Flap

The principle of utilizing a flap from the cheek, reversed upon itself as a hinge flap was attributed to Dupuytren by Labat (1833) Dieffenbach (1845) modified the technique by taking the flap from the nasolabial area thus minimizing the secondary scarring Dieffenbach folded the flap longitudinally to restore both the outer covering and inner lining of the ala (Fig 739) This method is similar to that employed to obtain a nasolabial flap to cover the skin of the nose. In male patients, the flap may include skin from below the nasolabaial fold for hair follicles are in the portion of the flap employed to restore the inner lining of the ala the hairs replace the nasal vibrissae

We favor the use of the nasolabial flap as a hinge-flap reversed upon itself to provide the nasal lining The operative procedure consists of outlining a measured tongue shaped or triangular flap from the base of the ala of the nose downward along the nasolabial fold (Fig 740*A*) The incision is made through the skin and subcutaneous tissue and additional subcutaneous tissue is included at the base of the flap to safeguard the blood supply The flap is raised and sutured to the borders of the nasal defect thus forming the inner lining of the reconstructed ala (Fig 740*B*) the external raw area is covered by a full thickness retroauricular graft (Fig 740C) The nasal ala restored by such a procedure (Fig 741) is usually quite thick in contour but may be thinned at a later date.

Composite Grafts of Skin and Cartilage

The use of composite grafts removed from the auricle consisting of a segment of auricular cartilage covered on both sides by skin to restore alar defects, was reported by König (1887) The method does not appear to have been utilized to any extent until interest was revived by Gillies (1943) who reported a case in which he had employed a composite graft consisting of a segment of auricular cartilage with the attached skin on one side This graft provided the lining and cartilaginous support for an ala and a

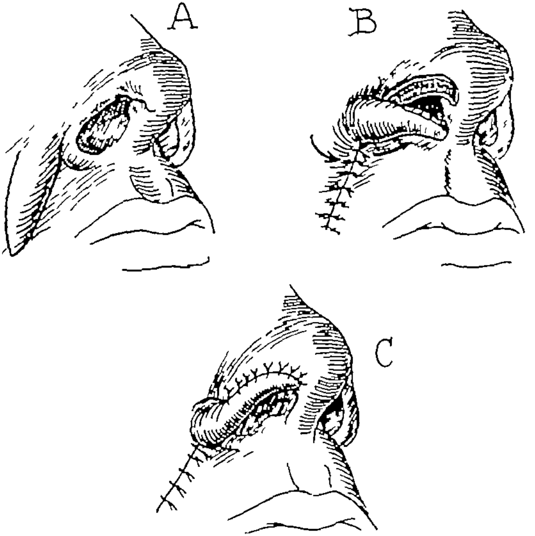

Fig 739 Nasolabial flap for restoration of alar border

A. Design of nasolabial flap.

B. The donor area of the flap is closed by direct approximation, a procedure which tends to approximate the base of the flap to the base of the ala.

C. The nasolabial flap is sutured to the border of the ala defect.

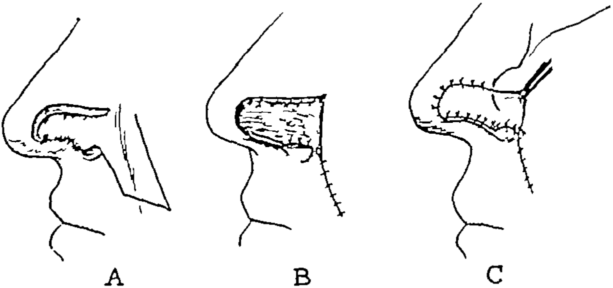

Fig 740. Reconstruction of ala with nasolabial flap Nasolabial flap turned in to form the inner lining of the nostril The outer surface is covered with a postauricular full thickness skin graft

FIG 741 Reconstruction of ala with nasolabial flap

A. Loss of right side of the nostril with marked contracture.
B. Photograph of patient following repair by nasolabial flap as shown in Figure 740

portion of the tip of the nose reconstructed by the up-and-down forehead flap technique following a dogbite The composite graft was implanted in a preliminary stage under the part of the forehead flap which was to form the ala Brown and Cannon (1946) used the König type of composite graft to restore alar margins and defects which involved portions of the ala.

TECHNIQUE OF THE COMPOSITE AURICULAR GRAFT Excision of scar tissue along the margin of the ala is a necessary prerequisite to obtain a recipient bed of well vascularized tissue. Hemostasis is essential for postoperative bleeding may prevent accurate apposition of the graft. The dimensions of the defect are measured and the composite graft is removed from the auricle.

A favorite donor site of König was the posterosuperior portion of the auricle (Figs. 742 and 743) We have also employed the posteroinferior area immediately above the antitragus and also the anterosuperior area. The secondary defect of the ear is usually repaired by direct approximation notching the helix border is avoided by the stepping or Z plastic techniques.

Another type of composite graft is removed from the base of the ala on the unaffected side, turned upside-down and employed as a wedge in the base of the deformed ala on the opposite side to provide increased length (Fig 744)

The graft is sutured to the edges of the defect and the inner layer of skin is approximated to the nasal lining with catgut sutures the outer skin layer is sutured to the skin border of the defect with fine Nylon. Intravestibular packing with moist cotton pledgets provides a satisfactory internal splint. In our experience composite grafts have healed satisfactorily without an external dressing (Fig 745)

VASCULARIZATION OF COMPOSITE GRAFTS When the raw edge of a composite graft consisting of a layer of cartilage covered on each side by a layer of skin is applied to the edge of the defect, the small contact surface restricts the area through which revasculari

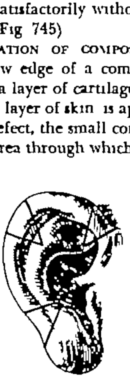

FIG 742. Areas of removal of composite grafts from the auricle.

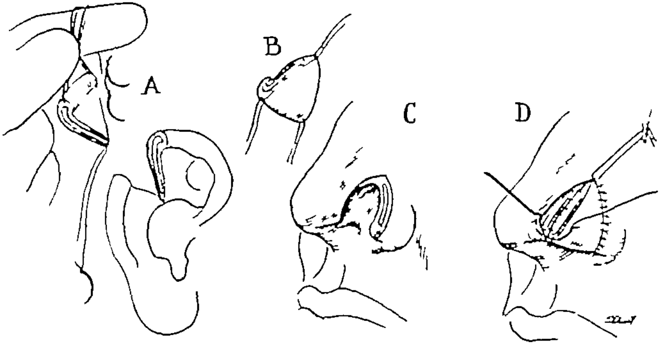

Fig 743 Technique of composite auricular graft to repair a nasal defect
A and B Composite chondrocutaneous graft removed from the auricle
C Nasal defect
D Composite graft inserted into nasal defect and sutured.

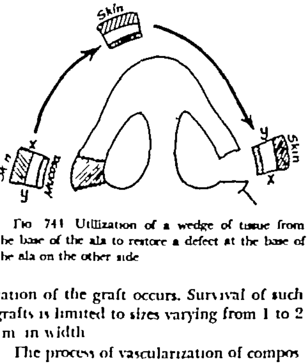

Fig 744 Utilization of a wedge of tissue from the base of the ala to restore a defect at the base of the ala on the other side

zation of the graft occurs. Survival of such grafts is limited to sizes varying from 1 to 2 cm in width

The process of vascularization of composite grafts is a practical consideration The role of the rich anastomotic vasculature of the dermis in pedicled skin flaps has been discussed *in Chapter 17 the flow of blood* along the length of the flap is transmitted by the dermal vessels. The more complex process in skin grafts is discussed in Chapter 15 During the initial period inosculation of vessels of the graft and host insures the survival of the graft until a definitive type of circulation with hemic flow is established by the ingrowth of host vessels into the graft The establishment of hemic flow *is essential to insure survival of the graft.* Highly vascularized tissues such as the nose and ear contain a proportionately denser network of endothelial channels than other tissues this accounts for the survival of composite grafts from these structures, despite the restricted surface of contact *through which the host vessels penetrate* If the surface of contact between graft and host is increased the chances of survival are better and larger composite grafts can be employed

The contact surface area is enlarged by turning down a hinged flap from the skin at the edge of the defect providing that the tissue is well vascularized (Fig 746) The composite graft should be placed over the

FIG 745. Composite graft from the auricle to repair a graft of the ala (Patient of Dr Blair O Rogers)

A. Malignant lesion of the left ala.

B Composite graft from the auricle repairing excision defect.

C. View from below of the reconstructed ala showing good contour

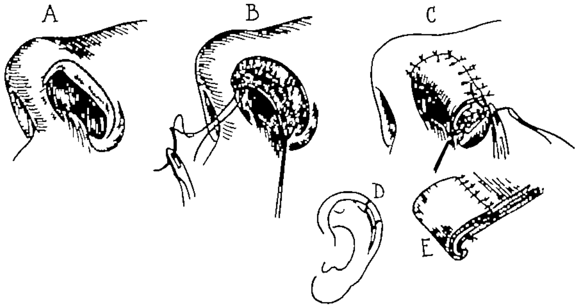

FIG 746 Hinge flap employed to increase the surface of contact between the composite graft and the recipient site.

A. Outline of incision for hinge flap

B. Hinge flap turned down.

C. Application of the composite graft to the recipient site.

D Auricular donor site of composite graft.

E. Illustrates details of suture of the composite graft to the recipient site.

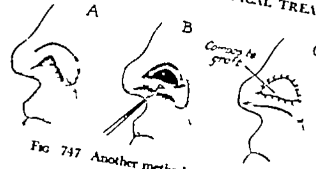

Fig 747 Another method of utilizing a composite graft

A. Outline of incision to mobilize the border of defect downward

B. The border of the defect has been mobilized downward.

C. Auricular composite graft in position repairing the secondary defect.

raw surface of increased size to produce a desirable overlap and to enlarge the area of apposition of graft and host. The structure of the composite graft can be simplified by eliminating the skin on one side of the graft and by providing the lining of the new ala with a nasolabial flap thus increasing the area of surface contact

A modification of the König procedure consists of utilizing a flap from the tissue bordering the alar defect to restore the alar margin (Fig 747) A composite auricular graft sutured into the secondary defect, receives nourishment from the entire circumferential edge of the graft

Composite Auricular Graft for Defects of the Base of the Ala and Adjacent Nasolabial Area

This technique which has been employed to reconstruct the nasolabial area after excision for carcinoma (Converse 1950) is also applicable for defects resulting from injury (Fig 748A B C) A strip of skin 0.5 cm in width is excised along the edge of the alar defect (Fig 748D) The graft thus has wider surface of contact with the edges the defects than by simple proximation and revascu tated (Fig 748F) A patt

made and the alar fold is indicated on the pattern by an ink line (Fig 748F) the pattern is then applied to the retroauricular area on the same side and placed so that the ink line lies over the retroauricular fold (Fig 748G) An incision is made through the auricular skin the skin is raised from the cartilage for a distance of 0.5 cm and the conchal cartilage and skin are sectioned (Fig 748H) The required area of retroauricular skin is removed with the composite graft which comprises the full thickness of the concha the fat is then trimmed from the base of the skin (Fig 748I)

The composite graft is now carefully sutured to the edges of the defect the edges of the conchal skin are sutured to the edges of the vestibular skin with 4-0 plain catgut and the edges of the graft are sutured into the edges of the defect (Fig 748J) The conchal skin is sutured to the postauricular skin (Fig 748K) along the anterior border of the nostril Narrow strip gauze or cotton pled gets moistened in saline are carefully packed into the vestibule to provide an internal support for the graft (Fig 748I) which is then covered with a nonadherent dressing A pressure dressing is maintained for a period of five days

A full thickness graft from the upper portion of the postauricular area is sutured into position to fill the conchal defect (Fig 749)

The extent of shrinkage depends upon the size of the graft and rapidity with which it becomes revascularized The color match is usually good and restoration of the full thickness of the ala and of the nasolabial area is achieved

Composite Grafts of Skin and Adipose Tissue

reader is referred to Chapter 20 for le of a skin-fat graft of hair bear sue to restore the eyebrow Sub hair follicles are if the graft is

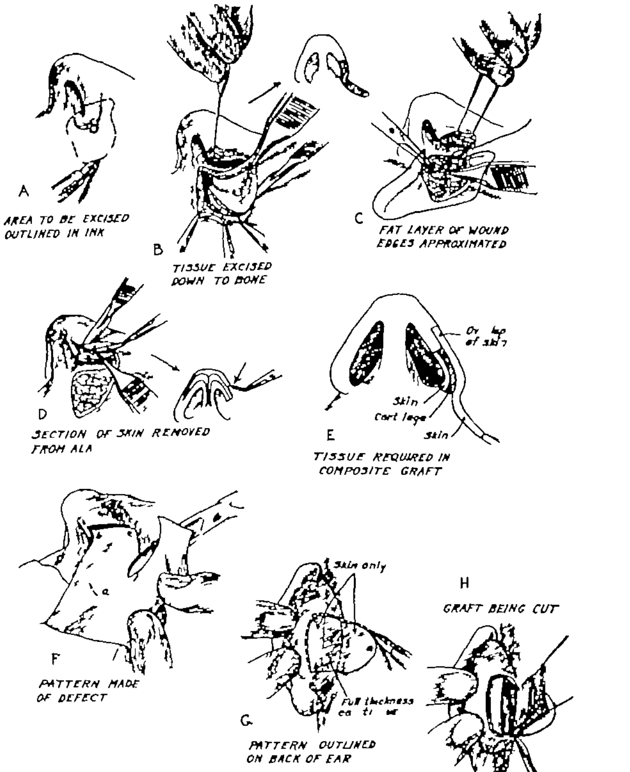

FIG 748. The wedge composite graft for nasolabial reconstruction. This technique has been used for the repair of defects caused by tissue resection for malignancy It is applicable to a defect due to trauma.

A and B. Drawings illustrating resection of the base of the ala and adjacent nasolabial area.

C. Illustrates the extent of the defect.

D The deep fat layer is sutured.

E. A strip of skin is excised from the edge of the alar defect.

F Plan of the reconstruction a graft comprising skin for the vestibular lining cartilaginous support and skin for the outer covering

G A pattern of defect is prepared.

H. The pattern is placed over the retroauricular area. The line of the alar fold overlies the retroauricular fold.

(*See continuation on next figure*)

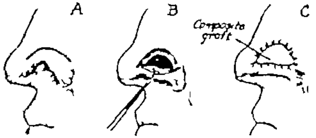

FIG. 747 Another method of utilizing a composite graft

A. Outline of incision to mobilize the border of defect downward.

B. The border of the defect has been mobilized downward.

C. Auricular composite graft in position repairing the secondary defect.

raw surface of increased size to produce a desirable overlap and to enlarge the area of apposition of graft and host. The structure of the composite graft can be simplified by eliminating the skin on one side of the graft and by providing the lining of the new ala with a nasolabial flap thus increasing the area of surface contact.

A modification of the König procedure consists of utilizing a flap from the tissue bordering the alar defect to restore the alar margin (Fig 747) A composite auricular graft sutured into the secondary defect, receives nourishment from the entire circumferential edge of the graft.

Composite Auricular Graft for Defects of the Base of the Ala and Adjacent Nasolabial Area

This technique which has been employed to reconstruct the nasolabial area after excision for carcinoma (Converse, 1950) is also applicable for defects resulting from injury (Fig 748*A* *B* *C*) A strip of skin 0.5 cm in width is excised along the edge of the alar defect (Fig 748*D*) The graft thus has a wider surface of contact with the edges of the defects than by simple edge to edge approximation and revascularization is facilitated (Fig 748*E*) A pattern of the defect is made and the alar fold is indicated on the pattern by an ink line (Fig 748*F*) the pattern is then applied to the retroauricular area on the same side and placed so that the ink line lies over the retroauricular fold (Fig 748*G*) An incision is made through the auricular skin the skin is raised from the cartilage for a distance of 0.5 cm. and the conchal cartilage and skin are sectioned (Fig 748*H*) The required area of retroauricular skin is removed with the composite graft which comprises the full thickness of the concha the fat is then trimmed from the base of the skin (Fig 748*I*)

The composite graft is now carefully sutured to the edges of the defect the edges of the conchal skin are sutured to the edges of the vestibular skin with 4-0 plain catgut and the edges of the graft are sutured into the edges of the defect (Fig 748*J*) The conchal skin is sutured to the postauricular skin (Fig 748*K*) along the anterior border of the nostril Narrow strip gauze or cotton pledgets moistened in saline are carefully packed into the vestibule to provide an internal support for the graft (Fig 748*L*) which is then covered with a nonadherent dressing A pressure dressing is maintained for a period of five days.

A full thickness graft from the upper portion of the postauricular area is sutured into position to fill the conchal defect (Fig 749).

The extent of shrinkage depends upon the size of the graft and rapidity with which it becomes revascularized. The color match is usually good and restoration of the full thickness of the ala and of the nasolabial area is achieved.

Composite Grafts of Skin and Adipose Tissue

The reader is referred to Chapter 20 for an example of a skin fat graft of hair bearing scalp tissue to restore the eyebrow Subcutaneous fat into which hair follicles are implanted must be preserved if the graft is

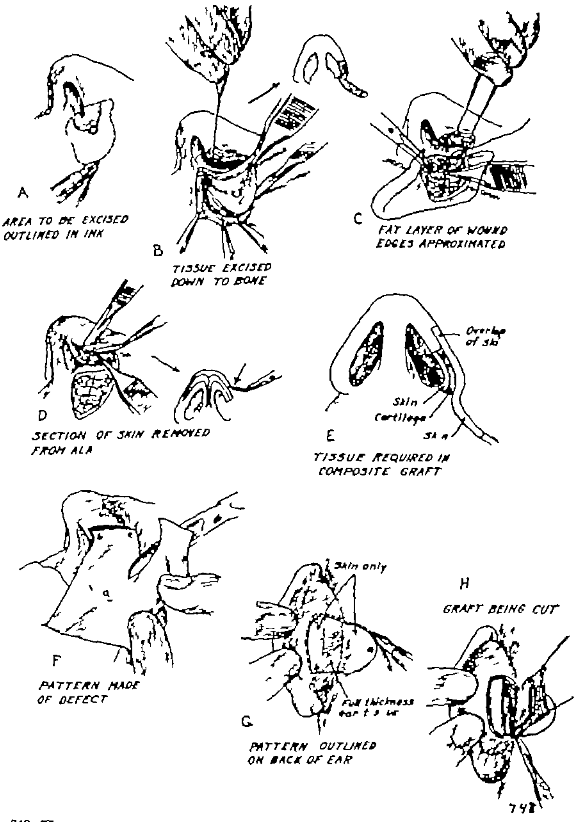

FIG. 748. The wedge composite graft for nasolabial reconstruction. This technique has been used for the repair of defects caused by tissue resection for malignancy It is applicable to a defect due to trauma.

A and B Drawings illustrating resection of the base of the ala and adjacent nasolabial area.

C. Illustrates the extent of the defect.

D The deep fat layer is sutured

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F Plan of the reconstruction a graft comprising skin for the vestibular lining cartilaginous support and skin for the outer covering

G A pattern of defect is prepared.

H. The pattern is placed over the retroauricular area. The line of the alar fold overlies the retroauricular fold.

(*See continuation on next figure*)

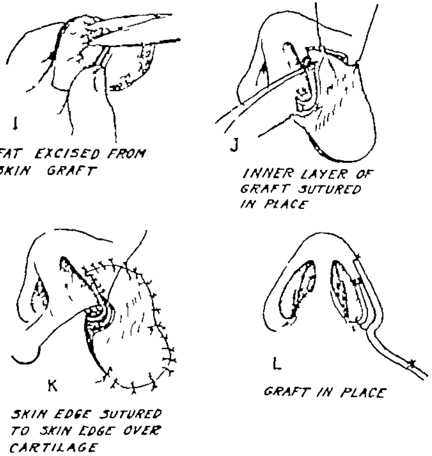


Fig 748 (*Continued*)

I Excision of the composite graft from the concha.

J The fat is excised from the dermal surface of the skin of the graft.

K. Suturing the composite graft in position.

L. *Suture of the skin edges to form the free margins of the reconstructed ala.*

M. Diagram of completed reconstruction.

(From J M. Converse, Plast. & Reconstruct. Surg 5:247 1950)

to remain hair bearing This type of graft should be of narrow dimensions to permit vascularization from the lateral aspects of the transplant.

A composite graft consisting of a full thickness segment of the ala may be excised from the unaffected ala and transplanted to the defective ala (Fig 744)

Retroauricular grafts with a thin layer of fat purposely left attached to the deep surface of the dermis, are transplanted to the area of the nasal tip Excision of the scarred skin exposes the perichondrium of the alar cartilage The skin fat graft is employed to avoid a depression in the grafted area The survival of such grafts is accounted for by the rich vascular supply of both donor and recipient sites.

Grafts of skin and fat removed from the lobe of the ear (Dupertuis, 1946) are employed for the repair of small defects of the nasal tip the medial portion of the ala and the columella (see Fig 791) The postoperative shrinkage of these skin-fat grafts must be considered when planning the reconstructive procedure.

Reconstruction of the Nose with Forehead Flaps

The forehead flap is the method of choice in defects of the nose too large to be repaired by composite auricular grafts or by

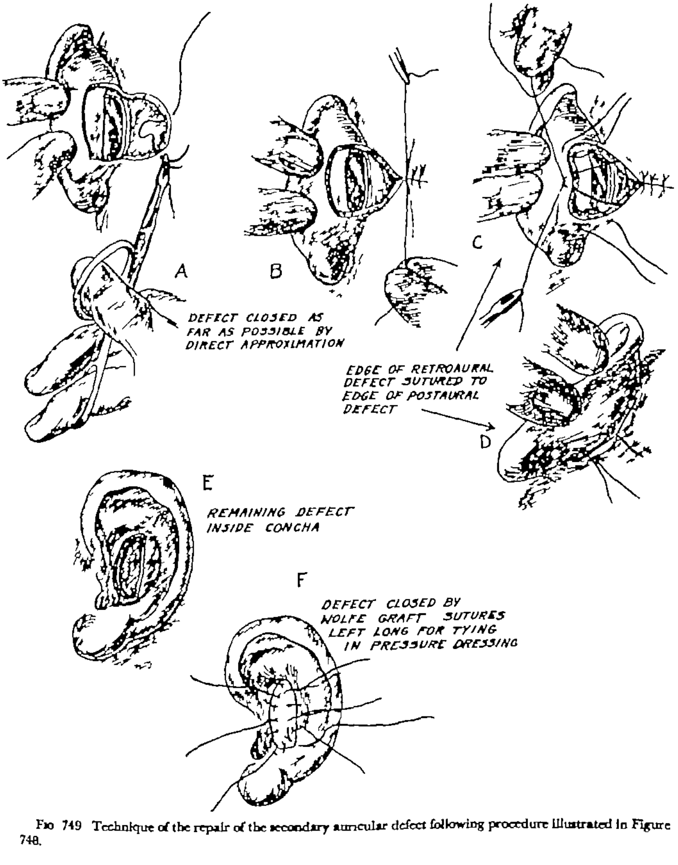


FIG 749 Technique of the repair of the secondary auricular defect following procedure illustrated in Figure 748.

flaps of adjacent tissue. When forehead tissue is available, reconstructing the nose with a forehead flap is advantageous because the skin of the forehead is adjacent to the nose it is similar in color and texture, and it has a good blood supply (Fig 750) An objection to the procedure is the secondary scarring of the forehead This however

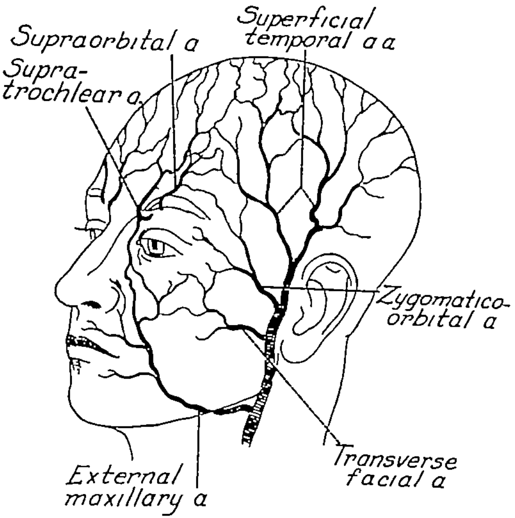


FIG 750 The blood supply of the forehead

can be minimized by various techniques (1) Utilizing a flap removed from the mid line area of the forehead (Kazanjian 1916) This procedure usually permits closure by direct approximation leaving only a linear scar without injuring the frontalis muscles because the flap is removed from an area devoid of musculature It will be recalled that there is an interval between the frontalis muscles in the mid line of the forehead. (2) Placing the defect on the side of the forehead (Converse 1912) rendering it less visible in the full face view in female patients, the defect can be hidden by the hair (3) Covering the secondary forehead defect with well-matched skin preferably from the post auricular or supraclavicular regions. (4) Avoiding damage to the frontalis muscle the most deforming secondary feature of the forehead flap technique is the absence of expressive movements of forehead resulting from the removal of a section of the frontalis muscle.

An additional advantage of the forehead flap is the absence of discomfort experienced by the patient in the Tagliacotian or other methods which employ the transfer of flaps from a distance For these reasons, the forehead flap is preferred as a source of skin for reconstructing the nose

Development of Reconstructive Rhinoplasty

It is doubtful whether any subject in surgery received more attention than that of reconstructive rhinoplasty during the nineteenth century Amputation of the nose by swords in battle or in duels, the prevalence

of "scrofulous diseases, syphilis noma in addition to cancer explain this interest. Keegan, whose book published in 1900 is a culminating point of this abundant literature states that in 1897 at least 152 reconstructive rhinoplastic operations had been reported in Europe. His book also gives an account of his personal experiences of 100 rhinoplastic operations during his five year stay in India. The outstanding reviews on the subject include those of Carpue (1816) von Graefe (1818) Delpech (1824) Labat (1834) Blandin (1836) Dieffenbach (1829–1833 and 1845–1848) Liston (1837) Zeis (1838) Velpeau (1839) Serre (1842) von Ammon and Baumgarten (1842) Jobert (1849) and Malgaigne (1948) The American edition of the translation from the French of Velpeau's textbook in 1852 included a report on the work of Pancoast and Mutter of Philadelphia and Mott, Post and Buck of New York (Gnudi and Webster 1950) In the latter part of the nineteenth century the works of von Szymanowski (1870) and of Verneuil (1877) are but two outstanding among many other valuable contributions

The nineteenth century literature was compiled and classified by Nélaton and Ombrédanne (1904) in a book in which the authors illustrated by drawings the various techniques previously described. The comprehensive treatise by Nélaton and Ombrédanne remains today one of the most reliable sources of reference for the surgeon Joseph (1931) gave a comprehensive review of this subject.

The historical reviews of Davis (1919 and 1941) of Fomon (1939) and the erudite treatise by Gnudi and Webster (1950) are more recent valued contributions in the English language

A study of the history of nineteenth century reconstructive procedures assists in understanding the development of modern forehead flap techniques.

In the early operations the median Indian flap was used exclusively That some difficulty with the vascularization of the flap was encountered is illustrated by the opinion of Dieffenbach who impressed by the fact that inadequately vascularized flaps became blue advocated ligating some of the nutrient vessels a precept violently opposed by many of his contemporaries, among them Blandin and Serre Leeches were also employed to assist in decongesting the blue flap due to venous embarassment.

The twisting of the base of the pedicle attaining an angle of 190 frequently resulted in vascular congestion and produced a kink at the root of the nose Surgeons hesitated to remove this kink by severing the pedicle in a second stage operation for fear of depriving the new nose of its vascular supply and also of imposing an additional operation upon the patient, a painful ordeal before the discovery of anesthesia Some surgeons also felt that the reconstructed nose would collapse after the pedicle was sectioned.

The disadvantage of the kink was alleviated by modifications introduced in the incisions outlining the base of the pedicle. Lisfranc in 1826 extended one incision lower than the other and Dieffenbach lengthened one incision until it reached the defect (Fig 751) thus reducing the twisting of the base of the pedicle and the resultant deprivation of blood supply

The immediate results of these operations appeared satisfactory Considerable shrinkage occurred in the postoperative period, however and the narial openings of the reconstructed nose became constricted. Larrey observed the late results of Blandin's and Lisfranc's reconstructions and found them "horrible and Dupuytren was liberal with his sarcastic remarks at the meetings of the Surgical Society Later in the nineteenth century Denonvilliers was to comment disdainfully that all that surgery accomplished was to replace a disgusting deformity by a ridiculous one." Most surgeons, however were in accord with Dieffenbach in attempting to relieve the sufferer laboring under such an affliction "at the sight of whom all

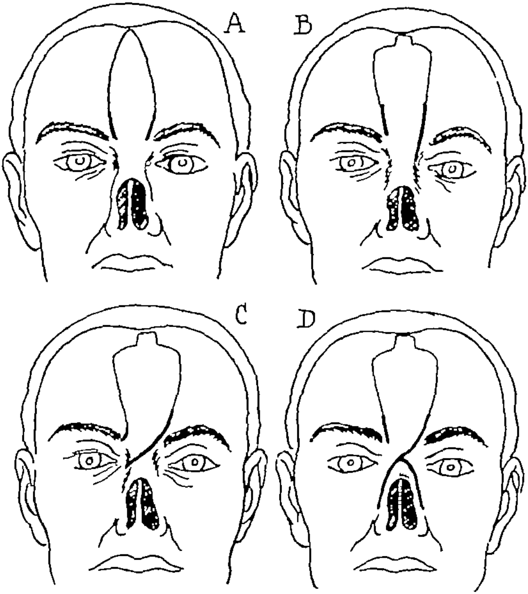


FIG 751 Evolution of incisions to diminish the twist of the base of the forehead flap (after Nélaton and Ombrédanne, 1904)

A. Incisions employed in the Indian rhinoplasty
B. Lisfranc's modification.
C Labat's modification.
D Dieffenbach's modification.

men turn in disgust and abhorence and at whose presence children cry and dogs bark.

The danger of a raw area under the flap open to suppuration fibrosis and contraction came to be realized The understanding of the necessity for providing a lining was the next forward step in the technique of forehead flap rhinoplasty In their early operations Carpue von Graefe Delpech Labat Blandin and Dieffenbach appear to have folded the distal end of the forehead to form the columella The alar portions do not appear however to have been lined an attempt was made to maintain the narial openings by rubber tubing Serre in 1812 stated by folding the end of the flap, placing the deep surface in contact with itself it would be easier to preserve the shape of the nose" According to Calderini (1812) Petrali was the first to emphasize the folding of the distal end of the flap upon itself in order to form the tip the alae and the colu

mella and eliminate raw areas in the lower part of the reconstructed nose.

Sédillot (1856) attributed postoperative retraction of the tip of the reconstructed nose to the presence of a raw surface on the posterior aspect of the new columella which became adherent to the raw surface under the remainder of the flap he advocated the raising of a flap from the upper lip to line the new columella (Fig 752)

To eliminate the raw area on the deep surface of the forehead flap surgeons began to utilize (1) the integument of the remaining portions of the nose, turned down as a flap as advocated by Volkmann (1874) (2) flaps from the adjacent facial area (Thiersch 1879) or (3) split thickness skin grafts (Lös sen 1898)

Additional problems confronting surgeons included the necessity for obtaining a flap of sufficient length to permit folding the end of the flap upon itself and a columella of adequate length According to Verneuil (1877) Auvert, a French surgeon practicing in Moscow had utilized a flap slanting across the forehead at an angle of 45 prior to 1850 and Ward described a similar oblique forehead flap in 1856 The oblique flap appears to have come into general use in the latter part of the nineteenth century and most of the flaps described by the German surgeons in this period assume an even more horizontal position with a wider base which includes the blood supply from the supraorbital vessels on one side.

A further advance was made when the reconstructed nose was provided with a skeletal framework. Ollier in 1858 suggested including the periosteum of the frontal bone in the forehead flap in the hope that bone would regenerate from the transplanted periosteum these attempts proved unsuccessful König (1886) included a strip of bone in the forehead flap and Israël employed a tibial bone graft for support. After von Mangold (1899) employed costal cartilage for the repair of a saddle-nose deformity

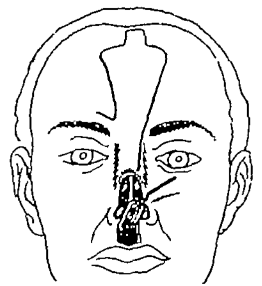


FIG 752. Denonvilliers procedure utilizing a flap from the upper lip to provide a lining and adequate anchorage of the columellar portion of the forehead flap (after Nélaton and Ombrédanne, 1904)

Nélaton (1902) implanted costal cartilage under the forehead flap previous to the transfer of the flap to the defective nasal area

In 1935 Gillies described a radical departure from the oblique forehead flap which had come into general usage a flap which ascended into the hair bearing scalp and then descended down into the forehead to which he gave the name up and down flap (Fig 753C D) This procedure permitted obtaining greater flap length while utilizing a flap of sufficient width to insure blood supply The scalping flap (Converse 1942) is a further extension of the up and down forehead flap technique (Fig 753E) In 1945 New described the sickle flap a delayed temporal flap for the reconstruction of partial defects of the nose (Fig 754) Kazanjian (1946) revived the Indian median flap adding technical improvements Schmid (1952) showed excellent results in reconstructing the nose piece-meal with horizontal supraorbital flaps (Fig 753F)

Forehead Faps for Nasal Reconstruction

The types of forehead flaps commonly employed are the median flap (Kazanjian 1946 Fig 753A) the oblique flap (Fig

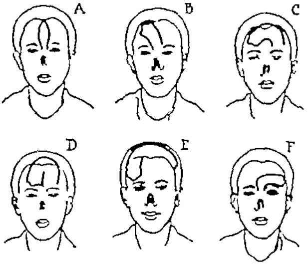


FIG. 753 Various types of forehead flaps utilized for nasal reconstruction.

A Median forehead flap.
B. Oblique forehead flap.
C. Up and down forehead flap.
D Modified up and down forehead flap.
E. Scalping flap.
F Horizontal supraorbital flap.

FIG 754 New's sickle flap

753B) the up-and-down flap (Fig 753C D Gillies, 1935) the scalping flap (Fig 753E Converse 1942) the horizontal supraorbital flap (Schmid 1952 Fig 753F) and the sickle flap (Fig 754 New 1945)

A unpedicled or bipedicled temporal flap, consisting of most or all of the skin of the forehead has occasionally been employed to provide skin coverage of the entire nose and adjacent areas of the cheeks (see Fig 1118 Chapter 29)

The median and scalping flaps are the two types of forehead flaps favored by the authors these flaps provide adequate forehead tissue for the repair of varying sizes of nasal defects. The oblique and horizontal flaps are used when pre-existing scars on the forehead contraindicate the use of a median or scalping flap New's sickle flap in our experience has two disadvantages (1) the pedicle of the flap is long requiring one or two preliminary delay operations, and (2) the base of the flap is kinked or twisted after transfer this tends to interfere with the blood supply of the flap

DELAY OF FOREHEAD FLAPS Satisfactorily designed forehead flaps require no preliminary delay for the blood supply is adequate thus assuring the survival of the tissues. Delay of a forehead flap by raising it from the host bed in a preliminary step results in the formation of scar tissue on the undersurface of the flap This scar tissue stiffens the flap, increasing the difficulty of in folding the distal portion of the flap to shape the alae and columella of the reconstructed nose the reconstructive procedure must be postponed until the flap becomes pliable. This inconvenience is unnecessary because a simple outlining incision without undermining is effective As previously discussed in Chapter 17 the blood supply of the scalp and forehead is derived from vessels which enter the circumference of the area not from perforating vessels

The Median Forehead Flap

The median forehead flap (Kazanjian 1946) is a vertical flap from the median section of the forehead, a modification of the flap employed in the original Indian rhinoplasty (Fig 755) It may be employed in various types of nasal defects and in full

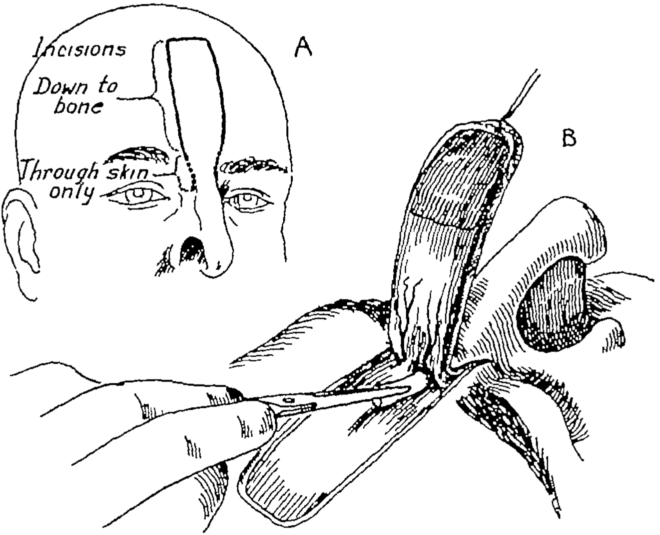


FIG 755 The median forehead flap

A. Outline of the flap. The dotted lines at the base of the pedicle illustrate the fact that the incisions extend through the skin only

B. Blunt dissection at the base of the pedicle to avoid injury of the supratrochlear vessels

thickness defects varying in size from the loss of the ala to the loss of the entire lower portion of the nose

Two parallel incisions over the forehead extending from the hairline to the root of the nose are joined at the hairline by a transverse incision. The incisions are extended through the soft tissues to the pericranium, the incisions being made in the mid-line of the forehead between the frontalis muscles which leave between them an interstice devoid of muscle The musculature of expression of the forehead is not interfered with a distinct advantage of this technique

The median forehead flap receives its blood supply from the paired supratrochlear and the dorsal nasal vessels.

The manner in which the incisions are made is important in order to obtain a flap of adequate length and to insure the flexibility of the base of the pedicle without endangering the blood supply The incisions extend from the hairline to a point immediately above the nasofrontal angle, and penetrate through the tissues to the periosteum covering the frontal bone from this point downward the lines of incisions are extended *through the skin only* medially to the eyebrow to a point lateral to the root of the nose Elevation by blunt dissection only is done in the lower portion of the pedicle of the flap at the junction of the forehead and the root of the nose This precaution and the fact that the incisions outlining the lower portion of the flap are made

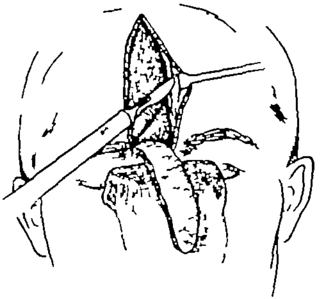


FIG 756. Median forehead flap. Two parallel releasing vertical incisions are made through the frontalis muscle to facilitate approximation of the borders.

(Figs 756 to 758 from V H Kazanjian, Surg Gynec. & Obst., 83 37 1946)

through the skin only prevent injury to the supratrochlear vessels The soft tissues over the lower portion of the forehead in the mid line and the root of the nose show a peculiar laxity which permits the action of the frowning muscles. This characteristic facilitates the twisting and downward mobilization of the base of the pedicle and provides sufficient length to the flap to make possible the restoration of the columella.

After raising the median flap, the secondary defect in the mid line of the forehead is closed by direct approximation and the flap is turned downward and sutured to the edges of the nasal defect. The pedicle of the flap is severed eighteen to twenty-one days later the lower portion of the nonutilized pedicle of the flap is then reinserted into the lower portion of the suture line. After direct approximation of the edges of the forehead defect puckering may tend to bring the medial ends of the eyebrows together such tension may be relieved in the second stage procedure, in which the pedicle of the flap is severed and the base of the median flap is replaced in the lower portion of the defect

Closure of the Forehead Defect

The resulting vertical scarline is inconspicuous particularly in patients of the older age group Although the forehead tissue is not as elastic as tissues of other parts of the face moderately large defects can be closed by approximation after undermining the forehead tissues on both sides. If the defect covers an area wider than 2 cm., the tissues are freely undermined on each side and one or two incisions are made on the under surface parallel to the incised edges, thus splitting the fibers of the frontalis muscle without penetrating through the subcutaneous fat into the skin (Fig 756) This procedure tends to loosen the skin of the forehead and permits approximation of the borders of the wound without undue tension

In more extensive defects, where a flap more than 2.5 cm wide is used closure by direct approximation may be difficult. Closure is made possible by two advancement flaps of the remaining forehead skin. Curved incisions, one along the hairline and the other above the eyebrows are extended if necessary as far as the temporal region the flaps are undermined and brought together to close the gap (Figs. 757 and 758) The re-

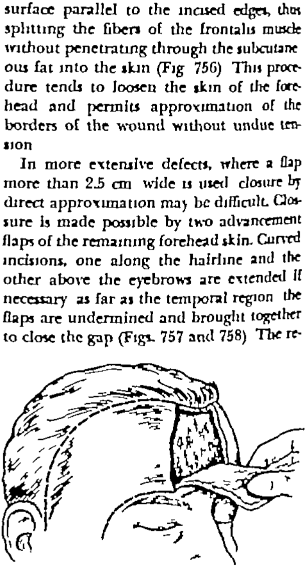


FIG 737 Median forehead flap Method of closing a large defect in the center of the forehead by making an advancement flap on each side of the forehead

FIG 758. Median forehead flap. Skin graft is sutured to the lower end of the forehead flap to form the inner lining of the defect.

sulting forehead scarline is conspicuous in some cases, but the scar can be excised at a later date and the wound resutured.

Swinging rotation flaps extending into the scalp may also be employed to close a defect resulting from a wide flap (Fig 759 Schimmelbusch 1895) Figure 760 shows the closure of a defect by rotation flaps.

After direct approximation of the edges of the forehead defect, puckering may tend to bring the medial ends of the eyebrows together such tension may be relieved in a second stage procedure, in which the pedicle of the flap is severed and the base of the median flap is replaced in the lower portion of the defect. Because the median forehead flap is removed from the area between the two frontalis muscles, the function of these muscles of expression remains intact. Careful planning is essential for the best utilization of the median flap

Applications of the Median Forehead Flap in Reconstruction of the Nose

The median flap is employed in a variety of nasal defects, and also in combination with other flaps or grafts

1 The median forehead flap provides a satisfactory skin covering in defects unsuitable for skin grafting such as defects with exposure of the nasal bones or deeply scarred radiated areas (see Figs. 624 and 625)

2 The median flap is the method of choice for the replacement of a deficient nasal lining In saddle-noses with shortening due to damage to the nasal framework and scarring of the nasal lining the median flap is introduced into the nasal cavity through a transverse incision across the cartilaginous

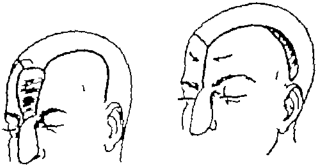


FIG 759 Technique of closure of median defect of the forehead with large rotation flaps (Schimmelbusch, 1895)

FIG 760. Photograph of patient showing donor area of median forehead flap for reconstruction of the nose, closed by mobilization of rotation flaps as illustrated in Figure 759

portion of the nose (see Fig 726) The end of the flap is sutured the skin surface is turned inward to form the nasal lining and the edges of the flap are sutured to the edges of the severed nasal lining

3 In full thickness defects of the nose, the median flap may be lined in a preliminary procedure by a full thickness retroauricular or composite septal graft. An alternate method (Kazanjian 1946) is to employ the median flap to furnish the lining of the defect The edges of the flap are sutured to the edge of the surrounding nasal lining The skin surface of the flap is turned toward the nasal cavity (Fig 761*A*) and a full thickness retroauricular graft is then applied to the raw surface of the flap to provide the outer covering (Fig 761*B*)

4 The median flap may be employed for the repair of defects of the tip and the columella The tissues at the base of the pedicle are loosened by blunt dissection to obtain a flap of sufficient length to reach the tip of the nose or the base of the columella (Fig 762)

5 The median forehead flap is indicated in defects involving the ala and also the lower portion of the lateral nasal wall A flap of adequate size is turned down, skin surface inward after the edges of the flap are sutured to the edges of the alar defect, a full thickness retroauricular graft is placed over the raw surface of the flap to supply the skin covering (Fig 763)

In reconstructing the ala and side of the nose satisfactory results have been obtained by lining the median forehead flap with a free composite graft from the septum (Converse, 1956 see Fig 785)

The Scalping Flap

The scalping flap has the advantage of placing most of the incisions behind the hairline, and the defect on the side of the forehead a relatively inconspicuous location The scalping flap technique makes possible the reconstruction of the nose in patients with narrow foreheads and a low hairline Brown and McDowell (1951) state that the oblique forehead flap cannot be used if the patient has a small forehead and they give the minimal dimensions of the forehead for the oblique flap Such limitations have not been encountered in the scalping flap (The authors have not had the opportunity of reconstructing the nose in

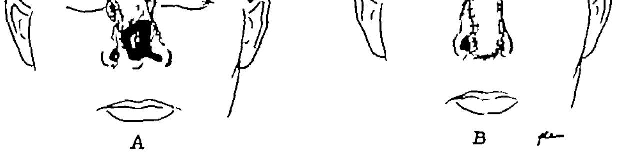


Fig 761 Median forehead flap

A. The forehead flap is everted to form the inner surface of the nose

B A full thickness skin graft is placed over the raw superficial surface of the flap.

Fig 762. Median forehead flap

A. Defect of the tip of the nose. The flap is raised Note that the base of the pedicle extends to the root of the nose.

B. Median flap sutured into defect and forehead defect closed by direct approximation

C. Final result obtained.

(From V H. Kazanjian and A Roopenian, Trans Am Acad. Ophth and Otol., 60 719 1956)

Fig 763 Median forehead flap

A. Loss of the lower half of the lateral wall of the nose.

B. Median forehead flap in position with its skin surface inward the outer raw surface of the flap was covered with a full thickness retroauricular graft in the same operating session.

C. Final result obtained.

the rare case of total loss of the nose in which the small-sized forehead might not provide sufficient tissue)

The width of the base of the flap supplied by the superficial temporal the supratrochlear and supraorbital vessels insures an abundant blood supply

The scalping flap can be loosened from the cranium until adequate length is obtained, thus permitting the in folding of the distal portion of this flap for the construction of the columella tip and alae.

The scalp hair should be closely clipped rather than shaved in order to preserve the

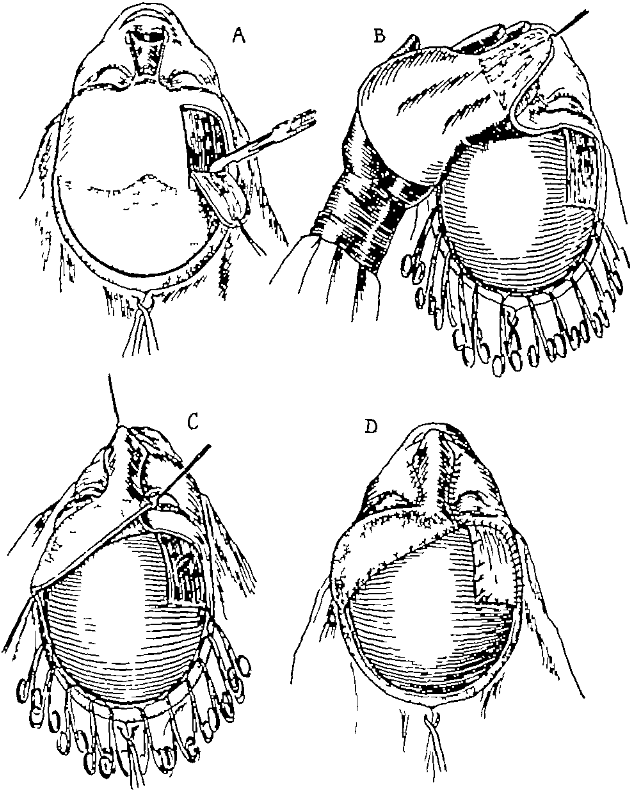


Fig. 764 Technique of the scalping flap

A. Forehead portion of the flap sharply dissected from the frontalis muscle

B Scalping flap raised from the pericranium.

C The pedicle of the flap is folded upon itself to close the flap.

D At completion of the flap transfer the permanent defect over the frontalis muscle is covered by a full thickness retroauricular or supraclavicular graft. The temporary pericranial defect is covered by a split thickness skin graft

(Figs. 764 and 765 from J. M. Converse S. Clin. North America, 39:335 1959)

hairline, an indispensable landmark. The flap is outlined in ink, previous to incising Incisions outlining the forehead portion of the flap extend through the skin only Careful elevation of the flap avoids injury to the nutrient vessels and the fibers of the frontalis muscle (Fig 764) The skin of the forehead is sharply dissected from the frontalis muscle fibers until the galea is sectioned. The remainder of the incision outlining the flap extends through the scalp and galea aponeurotica Extending upward from the lateral forehead incision the scalp incision curves upward and backward to the vicinity of the coronal line extending vertically upwards from the auricles After reaching this point the scalp incision extends across the mid-line and curves forward to a point approximately 5 to 8 cm. above the auricle. The flap is dissected from the pericranium by a cleavage plane established through the loose alveolar network between the pericranium and the galea (Fig 764*B*) The pericranium is preserved to furnish a bed for the temporary skin graft covering of the scalping defect.

With the exception of the portion removed from over the frontalis muscle the scalping flap includes all of the galea aponeurotica and the frontalis muscle on the opposite side of the forehead.

The flap must extend to the nose without tension. To make possible the in folding of the end of the flap the scalping flap should reach the level of the lips. Tension may be encountered when the flap is removed from the upper half of the forehead and it is relieved by an extension downward of the medial forehead incision Tension is also prevented by judicious choice of the side of the forehead, right or left, from which the flap is removed in most major nasal defects a portion of the nose is preserved, and the flap should be taken from the opposite side of the forehead.

After the flap has been transferred to the nasal area, the remainder of the pedicle is folded upon itself to eliminate the raw area line the new alae and form the tip and columella (Fig 765) The permanent defect on the forehead is covered by a full thickness retroauricular or supraclavicular graft placed over the frontalis muscle fibers (Fig 764*E*) The temporary forehead and scalp defect is covered by a split thickness skin graft (Fig 766) from the thigh or abdomen. When applying a pressure dressing to the grafted area compression of the pedicle should be avoided to prevent constriction of the blood vessels

The pedicle of the flap is sectioned after an interval of eighteen to twenty-one days (Fig 767) The skin graft dressing is removed from the scalp defect and the pedicle is opened and returned to its original site. It is not necessary to postpone the severance of the pedicle and the return of the remainder of the flap after twenty-one days. Adequate vascularization of the portion of the flap serving to reconstruct the nose has occurred and further postponement would render more difficult the return of the flap Fibrosis and contraction within the pedicle have not developed to any marked degree prior to twenty-one days and the flap is replaced without tension

Patients in whom the scalping flap technique has been employed are shown in Figures 768 769 770 and 771 (see also Fig 790)

APPLICATIONS OF THE SCALPING FOREHEAD FLAP The scalping forehead flap is employed for subtotal nose reconstruction because it provides a flap of sufficient length to fold the distal portion of the flap on itself to form the nasal tip the alae and the columella This flap may also be employed for smaller defects of the nose in such cases it is removed from the upper and lateral aspect of the forehead to minimize the secondary defect

The scalping flap may also be used in association with lining grafts or flaps these include full thickness retroauricular or supraclavicular grafts, a septal composite graft, a local hinge flap or a reversed nasolabial flap

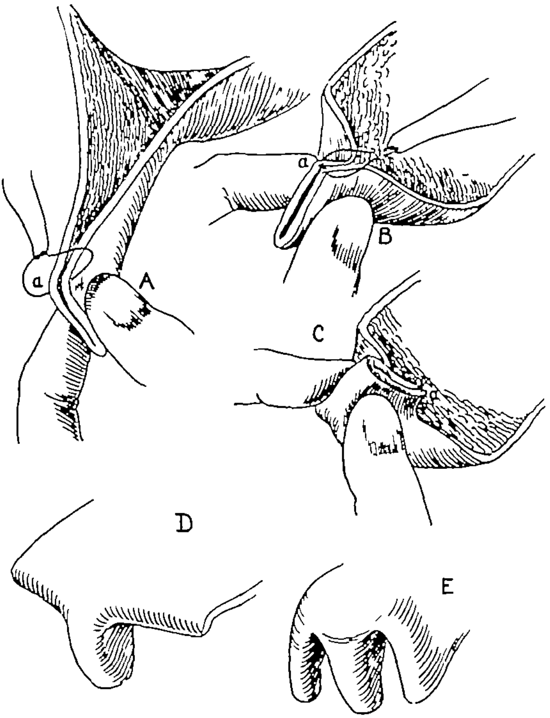


Fig 765 Infolding the distal end of the flap to reproduce the tip, columella and alae

A Suture placed to maintain the flaps in apposition (a)

B The distal part of the flap is infolded to form the alae A suture maintains the infolding by approximating point (a) to the undersurface of the flap. The degree of infolding determines the length of the new columella.

C Infolding completed

D and E Appearance of the nasal tip, columella and alae formed by the folded flap.

PLANNING THE FOREHEAD FLAP Correct planning and design of the forehead flap is an essential requisite for survival The use of pattern material for the design of pedicled flaps is described in Chapter 17 a similar procedure is required in the planning and reconstruction of the nose A piece of cloth can be used to simulate the flap A re-

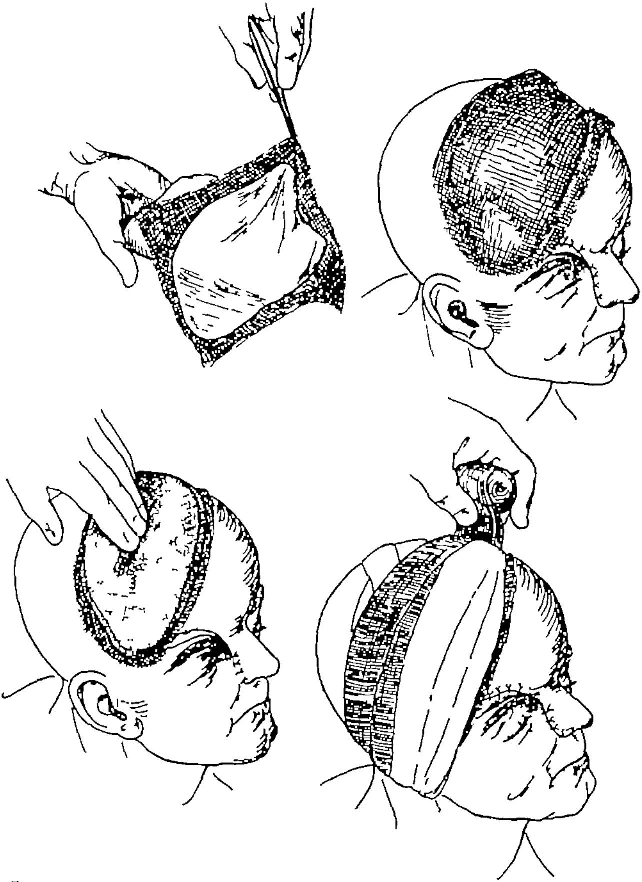


FIG. 766. Skin grafting of scalp defect after transfer of forehead flap. A split thickness graft over a backing of Nylon is placed over the defect and immobilized by sutures. A pressure-dressing is applied, care being taken to avoid pressure on the forehead flap.

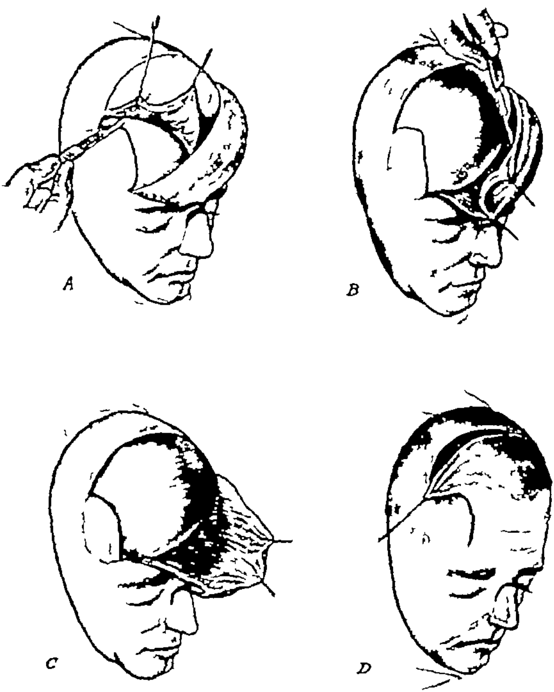


FIG 767 Second stage of scalping flap technique

A The attachment of the forehead flap to the nose is severed The temporary skin graft dressing is removed

B The flap is unrolled.

C The flap is ready for replacement.

D Suture of the flap into its original position Note suture of the galea aponeurotica

(From J M Converse Proc. Royal Soc Med 35 811 1942)

hearsal of the flap transfer procedure using the pattern material should always precede the actual operation In subtotal nose reconstruction particularly when the distal end of the flap is folded upon itself to form the columella and alae of the new nose pattern technique is of assistance in de mining the required dimensions. The pattern should then be sterilized and m available for use during the operation

A  B

Fig 768 Reconstruction of nose by scalping flap technique

A. Loss of lower part of nose as a result of automobile accident.

B. Result obtained by scalping flap technique. Note that the forehead defect is placed laterally

A  C

B

Fig 769 Stages in scalping flap transfer

A. Photograph showing scalping flap in position of transfer Note healed skin graft over the scalp defect.

B. Appearance after section and return of the remainder of the flap to its original position.

C. Appearance after regrowth of the hair and completion of the nasal reconstruction Note the defect placed laterally on the forehead where it is relatively inconspicuous.

Reconstruction of the Nose by Methods other than the Forehead Flap

The forehead flap is the method of choice in nasal reconstruction Tissue must be borrowed from another portion of the body when the forehead is unavailable as a donor site and large areas of the face in addition to the nose require a skin covering The inner aspect of the arm is hairless and thin and with the exception of its color the skin is suitable for nasal covering

The technique described by Taghacozzi

Fig 770 Immediate reconstruction of nose by scalping flap

A. Photograph shows nasal defect and scalping flap raised and ready for transfer

B Postoperative appearance of patient after nasal reconstruction

C. Profile view of reconstructed nose

D View from below

(Figs 770 and 771 from J M Converse *S Clin North America* 39 335 1959)

(1597) employs a retrograde delayed flap from the arm Because the Tagliacotian flap receives its blood supply from a distal base the proximal base being detached for transplantation a preliminary delay of the flap is necessary Joseph (1931) designed an arm flap with a more laterally situated pedicle base to improve the blood supply of the flap [illegible] the need for a preliminary delay [illegible] (Fig 772) A tubed pedi

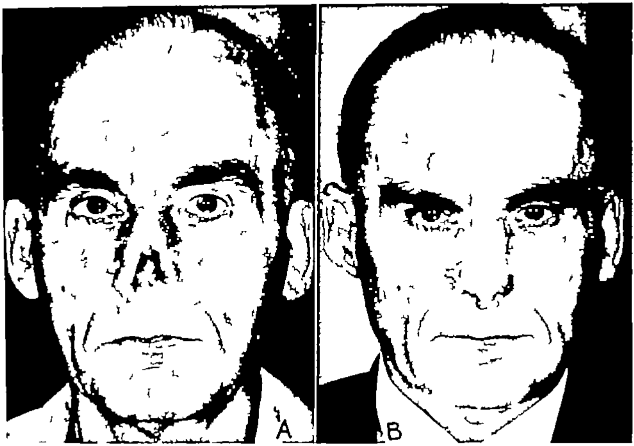


FIG. 771

A. Loss of most of the cartilaginous portion of the nose.

B. Reconstruction of scalping flap technique Note laterally situated defect on the forehead.

FIG 772. Brachial flap for nasal reconstruction (after Joseph, 1931)

Fig 773

A Photograph of patient who suffered burns of the side of the face upper lip, and lower part of the nose
B. Delayed arm flap transposed to supply skin to the tip of the nose lip and cheek
C. Postoperative photograph of patient.

cled flap with a proximal base may be employed to cover a defect of the nose and also an adjacent facial area (Fig 773)

In direct transfers of pedicled skin flaps from the arm to the nose strict immobilization of the upper extremity to the head is a necessary requirement to insure normal healing of the brachial flap and recipient site

A number of methods have been employed to secure immobilization Tagliacozzi used a leather harness. Malgaigne achieved fixation by an ingenious support which combined a cloth jacket and harness (see Fig 133 Chapter 17) Adhesive tape can be used for immobilization (Fig 773) Another method of immobilization is a plaster of Paris bandage head cap additional plaster bandaging forms a splint around the arm and thus maintains the upper extremity and the head in strict immobilization

Other types of distant flaps have been employed The acromiopectoral flap (Gillies, 1935) is detached at its medial or thoracic

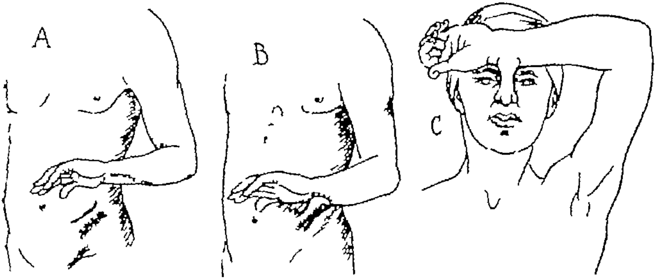


Fig 774 Transfer of abdominal tubed pedicled flap for nasal reconstruction
A. Oblique abdominal tubed pedicled flap raised from the left side of the abdomen.
B. Insertion on the radial aspect of the wrist.
C. The salute position for transfer of the abdominal tubed pedicled flap to the nose via the wrist (Kilner 1937)

extremity and is then transferred to the nasal region (see Fig 435 Chapter 17) An abdominal tubed pedicled flap may also be transferred to the nose by way of the wrist Another position of transfer for this flap is the "salute position (Fig 774) advocated by Kilner (1937) The upper end of an oblique abdominal tubed pedicled flap is attached to the radial aspect of the wrist (Fig 774*A* *B*) In a subsequent stage the lower end of the tubed pedicled flap is detached from the abdomen and the flap is transferred to the face by way of the wrist where it is implanted in the nasal area The dorsal aspect of the forearm is placed against the forehead and immobilized in the position illustrated in Figure 774*C* with the volar aspect of the forearm and hand facing forward

The flap is severed from its connection with the arm eighteen to twenty-one days after the flap transfer Sufficient tissue must be left attached to the nose in order that the alae and columella can be constructed in a subsequent stage

In addition to the risks attending the transfer of a flap from a distant area and the discomfort endured by the patient, results obtained in nasal reconstruction by distant flaps have not been as satisfactory as those obtained from the forehead. The color and texture of the transplanted skin are less satisfactory and the flap is usually too bulky especially when abdominal skin is transferred because of the thick dermis and subcutaneous adipose layer

Technical Details in Nasal Reconstruction

In reconstructing the lower part of the nose, the tip columella and alae are formed by in folding the end of the forehead flap (see Figs. 765 and 775) This technique requires a flap of adequate length and well vascularized to allow for the deprivation of the blood supply which results from the folding

When reconstructing the lower cartilaginous portion of the nose it is an esthetic advantage to extend the flap upward over the entire dorsum this technique assures continuity and avoids a horizontal line of junction between the lower reconstructed portion and the upper unaffected part of the nose Vascularization of the reconstructed area is also more satisfactory when the major portion of the flap rests on a bed of well vascularized tissue.

COVERING THE RAW AREAS AFTER MOBILIZA

FIG 775. Forming the alae and columella. The end of the forehead flap is folded in the manner illustrated and the bases of the new alae and columella are sutured to the prepared sites.

TION OF THE FOREHEAD FLAP USE OF SKIN *HOMOGRAFTS AND HETEROGRAFTS.* The scalping forehead flap technique leaves a raw *area over the anterior portion of the cra*nium a portion of the area remains as the definitive defect, for the forehead skin of the area is used in the reconstructive procedure The remaining raw area is a temporary defect only because it is covered by the remainder of the scalping flap after the pedicle is severed and the flap returned to its original location.

The permanent defect on the forehead is grafted immediately after the scalping flap *is raised a full thickness graft from the* retroauricular and postaural region or from the supraclavicular area is used to obtain a good color match with the skin of the fore head This full thickness graft is applied at the first operation because of two considera tions the newly created raw area over the forehead is a favorable bed for survival and fibrosis which may affect the normal func *tion of the frontalis muscle is prevented*

Repair of the secondary defect, produced by the removal of skin from behind the ear and over the mastoid area may be done in a later stage The skin edge of the defect near the border of the auricle is sutured to the skin edge of the defect over the mastoid the auricle is thus temporarily pinned back A split thickness graft is used in a later operation to cover the raw surface which remains after the auricle has been released

The temporary defect over the forehead *and scalp is usually covered by thin split* thickness autografts removed with the der matome from the abdomen or thigh Thiersch grafts provide adequate tempo covering until they are excised pr the severance of the pedicle [illegible] turn of the major portion of [illegible] its original position These tem[illegible]

should be as thin as possible in order that the donor area of the graft may heal with rapidity and with minimum scarring To save additional operating time and to avoid producing an additional wound frozen dried human homografts and heterografts of embryonic bovine skin have been em ployed (Rogers, Converse and Silvetti 1957) A tissue bank supplies both of these tissues. Although the transient protective covering of homografts and heterografts is only of ten- to fifteen-day duration ade quate protection has been obtained until the pedicle is severed and the remainder of the flap is returned. Homografts or hetero-grafts are less satisfactory than autografts they should therefore be reserved for older or debilitated patients in whom the ad ditional trauma resulting from the donor area wound is contraindicated.

THE USE OF LOCAL FLAPS IN CONJUNCTION WITH A FOREHEAD FLAP It is advisable to obtain a maximum amount of side-to-side apposition between the tissues of the host and the raw surface of the forehead flap In addition to the obvious advantage of an increased blood supply these adjacent flaps also assist in lining the forehead flap The most commonly employed lining flap is the skin of the remaining stump of the nose turned down as a hinge-flap (Figs. 776 and 777) The flap is outlined and raised from its bed in a preliminary delaying step if the border of the stump is scarred Hinge flaps may also be employed from the re-maining stumps of the alae (Fig 778C D) when the bases of the alae are absent, small nasolabial flaps may be raised from the ad jacent cheek area to supply the lining In subtotal nose reconstruction when the col umella must be provided a turned up hinge flap from the central portion of the lip (Fig 778C to E) is essential to line the posterior aspect of the new columella and also to pro-vide adequate anchorage of the new col umella base an area of diminished vascu larity because it is the most distal portion of the flap

Remaining local tissue should be em ployed whenever possible to restore the alar border for the totally reconstructed bor der can never approximate the delicacy of nasal tissue. In repair of unilateral defects which involve the ala and the side of the nose a triangular flap prepared from the edge of the defect on the medial side, is turned down to join the forehead flap (Fig 779 & 781 *D* to *F*) This procedure produces a natural appearance of the medial portion of the alar border particularly at the junc tion of the ala and the tip of the nose, and also avoids an end-to-end junction of the forehead flap with the tip which may other wise produce a notching effect. A similar flap can be fashioned from the alar stump The entire alar border may be formed of nasal tissue by joining the flap from the alar stump with the medial triangular flap

COMPOSITE GRAFTS FROM THE SEPTUM IN NASAL RECONSTRUCTION (Converse, 1956) A satisfactory type of lining for a forehead flap when reconstructing defects of the lateral wall of the nose involving the ala is a composite graft of cartilage and skin for the three constituent layers of the ala the cutaneous covering cartilaginous support and vestibular lining Either a conchal com posite graft with the anterior auricular skin attached (Gillies 1943) or a composite graft from the septum is used. A graft from the septum is readily available in the im mediate vicinity of the defect and is usually of adequate size and shape The use of a flap from the septum for the repair of de-fects of the lateral nasal wall discussed earlier in this chapter (see Fig 737) has the disadvantage of creating a large perfora tion of the septum. Sufficient septal carti lage covered with mucoperichondrium is usually available for transplantation

The composite graft is usually removed from the septum on the side which shows a suitable curvature (Fig 780*A* *B*) A verti cal incision is made through the mucoperi chondrium and septal cartilage the incision must not extend through the mucoperi

FIG 775 Forming the alae and columella. The end of the forehead flap is folded in the manner illustrated and the bases of the new alae and columella are sutured to the prepared sites

TION OF THE FOREHEAD FLAP USE OF SKIN HOMOGRAFTS AND HETEROGRAFTS. The scalping forehead flap technique leaves a raw area over the anterior portion of the cranium a portion of the area remains as the definitive defect, for the forehead skin of the area is used in the reconstructive procedure The remaining raw area is a temporary defect only because it is covered by the remainder of the scalping flap after the pedicle is severed and the flap returned to its original location

The permanent defect on the forehead is grafted immediately after the scalping flap is raised a full thickness graft from the retroauricular and postaural region or from the supraclavicular area is used to obtain a good color match with the skin of the forehead This full thickness graft is applied at the first operation because of two considerations the newly created raw area over the forehead is a favorable bed for survival and fibrosis which may affect the normal function of the frontalis muscle is prevented.

Repair of the secondary defect, produced by the removal of skin from behind the ear and over the mastoid area may be done in a later stage The skin edge of the defect near the border of the auricle is sutured to the skin edge of the defect over the mastoid the auricle is thus temporarily pinned back. A split thickness graft is used in a later operation to cover the raw surface which remains after the auricle has been released

The temporary defect over the forehead and scalp is usually covered by thin split thickness autografts removed with the dermatome from the abdomen or thigh Thiersch grafts provide adequate temporary covering until they are excised prior to the severance of the pedicle and the return of the major portion of the flap to its original position These temporary grafts

should be as thin as possible in order that the donor area of the graft may heal with rapidity and with minimum scarring To save additional operating time and to avoid producing an additional wound frozen dried human homografts and heterografts of embryonic bovine skin have been employed (Rogers Converse and Silvetti 1957) A tissue bank supplies both of these tissues Although the transient protective covering of homografts and heterografts is only of ten- to fifteen-day duration adequate protection has been obtained until the pedicle is severed and the remainder of the flap is returned. Homografts or heterografts are less satisfactory than autografts they should therefore be reserved for older or debilitated patients in whom the additional trauma resulting from the donor area wound is contraindicated.

THE USE OF LOCAL FLAPS IN CONJUNCTION WITH A FOREHEAD FLAP It is advisable to obtain a maximum amount of side-to-side apposition between the tissues of the host and the raw surface of the forehead flap In addition to the obvious advantage of an increased blood supply these adjacent flaps also assist in lining the forehead flap The most commonly employed lining flap is the skin of the remaining stump of the nose, turned down as a hinge-flap (Figs. 776 and 777) The flap is outlined and raised from its bed in a preliminary delaying step if the border of the stump is scarred Hinge flaps may also be employed from the remaining stumps of the alae (Fig 778*C D*) when the bases of the alae are absent, small nasolabial flaps may be raised from the adjacent cheek area to supply the lining In subtotal nose reconstruction when the columella must be provided, a turned up hinge flap from the central portion of the lip (Fig 778*C* to *E*) is essential to line the posterior aspect of the new columella and also to provide adequate anchorage of the new columella base an area of diminished vascularity because it is the most distal portion of the flap

Remaining local tissue should be employed whenever possible to restore the alar border for the totally reconstructed border can never approximate the delicacy of nasal tissue. In repair of unilateral defects which involve the ala and the side of the nose a triangular flap prepared from the edge of the defect on the medial side, is turned down to join the forehead flap (Fig 779 & 781 *D* to *F*) This procedure produces a natural appearance of the medial portion of the alar border particularly at the junction of the ala and the tip of the nose and also avoids an end to-end junction of the forehead flap with the tip which may otherwise produce a notching effect A similar flap can be fashioned from the alar stump The entire alar border may be formed of nasal tissue by joining the flap from the alar stump with the medial triangular flap

COMPOSITE GRAFTS FROM THE SEPTUM IN NASAL RECONSTRUCTION (Converse, 1956) A satisfactory type of lining for a forehead flap when reconstructing defects of the lateral wall of the nose involving the ala is a composite graft of cartilage and skin for the three constituent layers of the ala the cutaneous covering, cartilaginous support and vestibular lining Either a conchal composite graft with the anterior auricular skin attached (Gillies 1943) or a composite graft from the septum is used. A graft from the septum is readily available in the immediate vicinity of the defect and is usually of adequate size and shape. The use of a flap from the septum for the repair of defects of the lateral nasal wall discussed earlier in this chapter (see Fig 737) has the disadvantage of creating a large perforation of the septum Sufficient septal cartilage covered with mucoperichondrium, is usually available for transplantation

The composite graft is usually removed from the septum on the side which shows a suitable curvature (Fig 780*A B*) A vertical incision is made through the mucoperichondrium and septal cartilage, the incision must not extend through the mucoperi

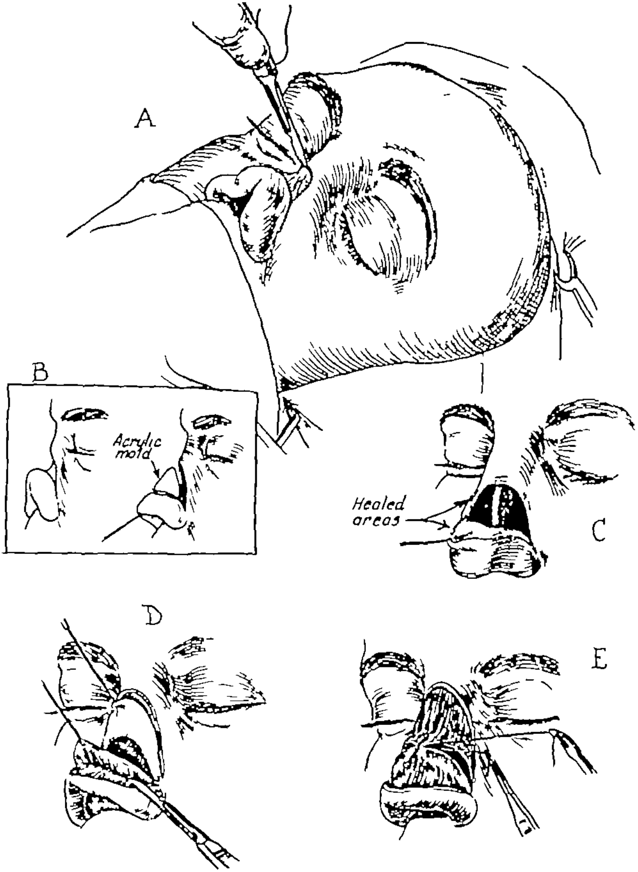


FIG 776 Lengthening the nose and reconstruction of nasal defect by use of local hinge flaps and scalping forehead flap.

A. Loss of nasal tissue resulting in shortening of the nose and defect of nasal tip and columella.

B. Lengthening obtained by downward mobilization of the tip. The position of the tip is maintained by an acrylic mold.

C. Appearance of nasal defect after healing.

D. Outline of local hinge flaps to restore the lining.

E. Suture of the hinge flaps.

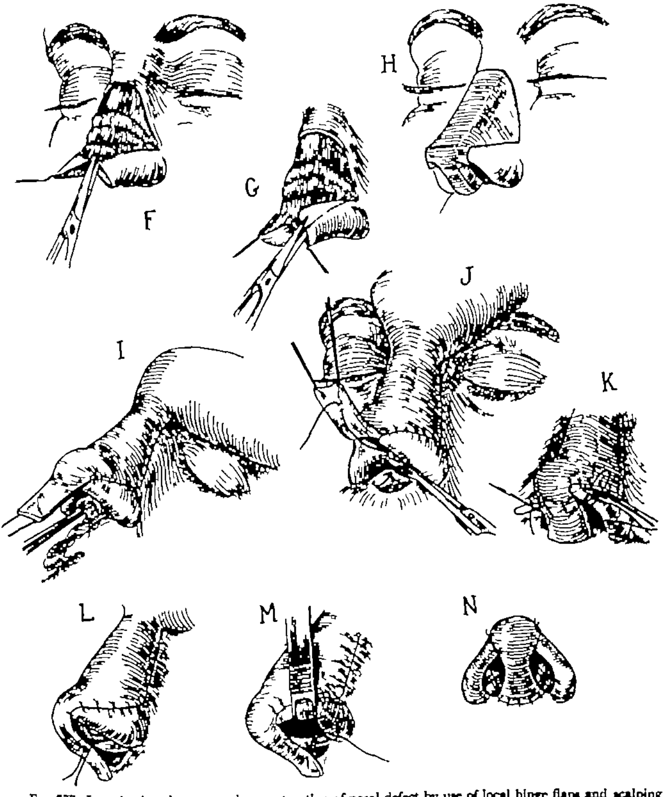


FIG. 777 Lengthening the nose and reconstruction of nasal defect by use of local hinge flaps and scalping forehead flap (*Continued*)

F The tip area is split in order to permit the replacement of the alae in the correct position.

G Excision of skin from the border of the defect.

H. A cloth pattern is made of the defect.

I. Scalping flap in position.

J K, L, M and N Suture of the columellar portion of the flap.

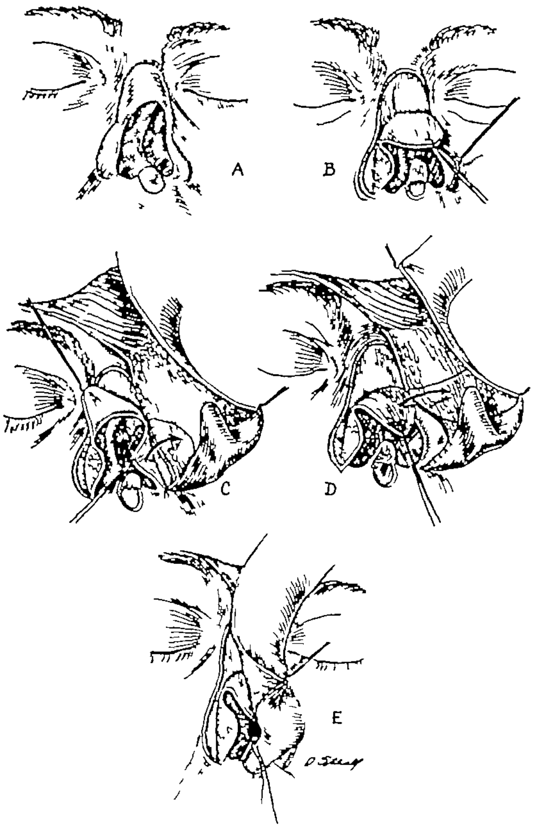


Fig 778. Local lining flaps in nasal reconstruction

A Outline of dorsal flap from the nasal stump, hinge flaps from the base of the ala and the flap from the median portion of the lip.

B Demonstrating the various flaps turned in for lining

C The arrow indicates the triangular area on each side which is not covered by the flap from the nasal dorsal stump. These areas are covered by the hinge-flaps from the alar stumps.

D The arrow indicates the position the flap from the nasal dorsal stump will occupy The left hinge-flap from the alar stump has been sutured into position.

E. Suturing of lining flaps being completed

(Figs 778 and 779 from J M. Converse S Clin North America, 39.335 1959)

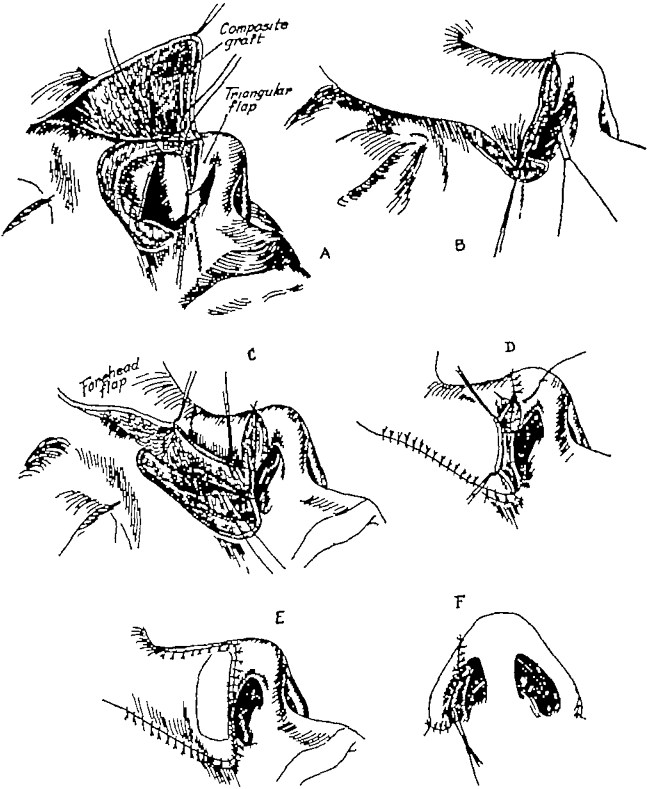


FIG. 779 Reconstruction of nasal defect by scalping flap and composite septal graft

A. Flap lined with composite graft being sutured to the median edge of the defect. Note triangular median flap.

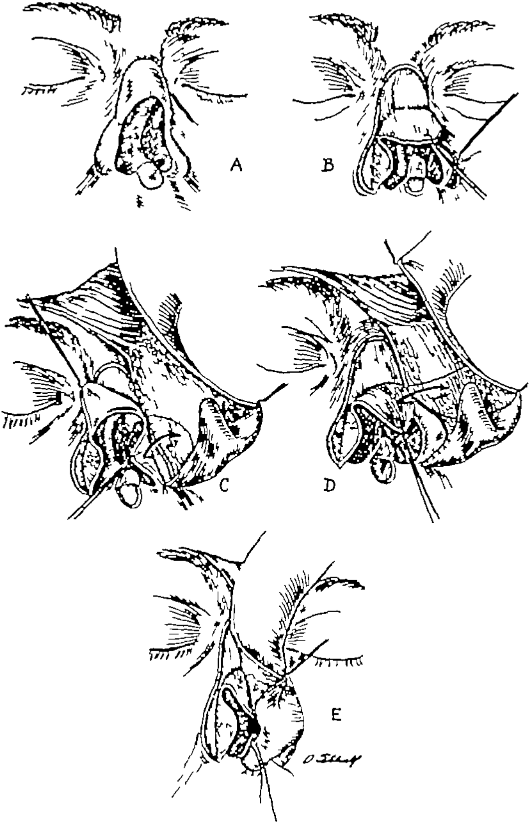
B. Triangular median flap sutured to the composite graft.

C. Composite graft sutured to the hinge-flap from the stump of the ala.

D Completing the suture at the alar border

E. Operation completed. The dotted outline indicates the position of the composite graft.

F Illustrates the position of the median triangular flap and the reconstructed ala.



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(Figs. 778 and 779 from J. M. Converse, S. Clin. North America, 39:335, 1959.)

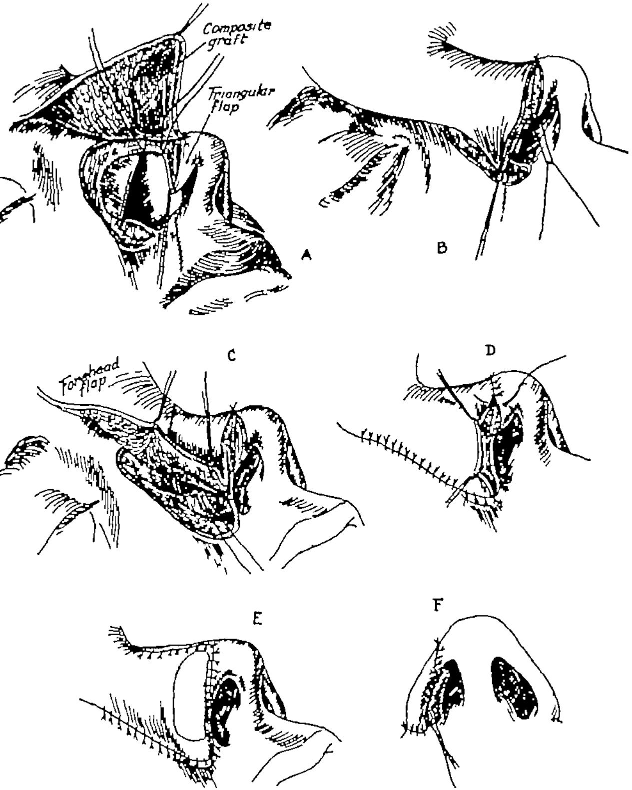


Fig 779 Reconstruction of nasal defect by scalping flap and composite septal graft
Flap lined with composite graft being sutured to the median edge of the defect. Note triangular median

Triangular median flap sutured to the composite graft.
Composite graft sutured to the hinge-flap from the stump of the ala.
Completing the suture at the alar border
Operation completed. The dotted outline indicates the position of the composite graft.
Illustrates the position of the median triangular flap and the reconstructed ala.

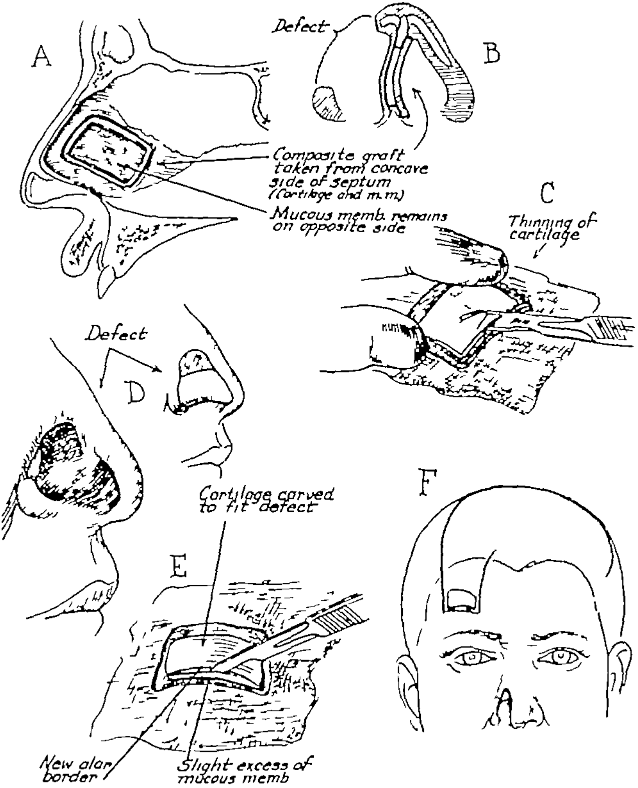


FIG. 780. Reconstruction of alar defect by means of septal composite graft and forehead flap.
A and B. Outline of area of septum from which composite graft is removed.
C. Thinning of the cartilage by shaving off slices of cartilage.
D. Defect of lateral wall of the nose.
E. Trimming the distal border of the cartilage graft in order to reproduce the curve of the alar border.
F. Position of the septal composite graft under scalping forehead flap.
(Figs. 780 to 787 from J. M. Converse. Tr. Latin American Congress of Plastic Surgery. 19[illegible].)

chondrium on the opposite side of the septum.

Additional incisions outline the graft. When a large graft is required care should be taken to leave a sufficient dorsal support and also an anterior buttress of cartilage to prevent depression along the dorsum of the nose and retraction of the columella The outlining incisions are extended backward to the perpendicular plate of the ethmoid.

The surface area of mucoperichondrium in the graft should always exceed that of the cartilage to increase the area of revascularization. In removing the composite graft from the septum the mucoperichondrium is raised from the cartilage over the required distance and the septal cartilage is severed at a suitable level the graft thus consists of mucoperichondrium and a smaller piece of cartilage. In reconstruction of the ala the required curvature is obtained by removing a suitable portion of curved septal cartilage (Fig 780*B*) A suitable curvature for the ala can be obtained for slight degrees of curvature are present in every septum After the composite graft is removed from the septum the intact mucoperichondrium on the opposite side prevents a septal perforation Re-epithelization of the raw surface of the mucoperichondrium is a relatively rapid process

The septal composite graft is imbedded under the forehead flap in a preliminary stage. Implantation of the graft on the undersurface of the portion of the forehead flap is achieved in the following manner The septal cartilage, when unduly thick is thinned by excision of thin slices from the surface (Fig 780*C*) An incision outlines the portion of the forehead flap which will serve to provide the missing ala The forehead flap skin is raised from the frontalis muscle (Fig 781*A*) The composite graft is sutured to the undersurface of the flap with fine catgut sutures (Fig 781*B*) the edges of the flap are then sutured to the skin edges of the host bed (Fig 781*C*) A moderately compressive pressure dressing is applied over the forehead for a period of approximately five days.

An interval of approximately 6 weeks should be permitted to elapse in order that the composite graft may become vascularized and healed to the forehead flap contraction occurs during this period and therefore minimizes shrinkage after transfer of the flap The forehead flap is raised after this interval and transferred to the nose restoring the defect (Fig 782)

Figures 783 784 785 786 and 787 are examples of the scalping forehead and the median forehead flap techniques employed in conjunction with the septal composite graft technique.

The immediate transplantation of the septal composite graft has been attempted to restore the lining at the time of the forehead flap transfer The rich vascularization may lead to the assumption that such a graft will result successfully In our experience however shrinkage and contraction cause a disappointing distortion of the alar border It seems preferable therefore for the shrinkage to occur in the forehead flap prior to the transfer

The advantages of the septal composite graft in reconstruction of defects involving the alar border are 2 fold (1) the length of the forehead flap is diminished for the infolding of the distal end of the flap is not a requirement the lining is provided by the composite graft and (2) the risks involved in the folding of the distal end of the flap with its attendant diminution of the blood supply are eliminated

THE USE OF THE SEPTAL REMNANTS TO PROVIDE SKELETAL SUPPORT FOR THE RECONSTRUCTED NOSE. Parts of the cartilaginous septum usually remain when the defect involves most of the cartilaginous portion of the nose and may be utilized to provide support for the reconstructed nasal tip Adequate length of flap providing sufficient length to the columella is an essential condition to obtain satisfactory projection of the tip of the reconstructed nose (Fig 790-1)

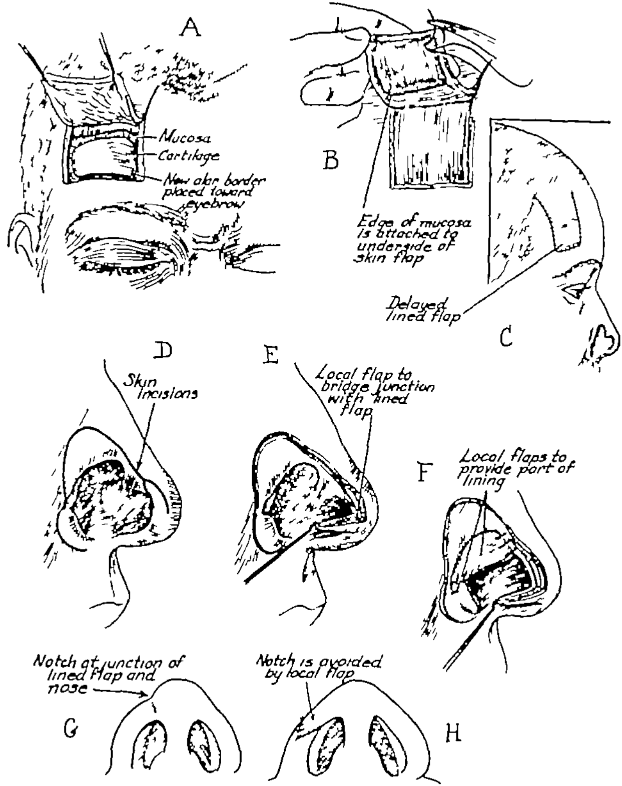


FIG 781 Reconstruction of alar defect by means of septal composite graft and forehead flap (*Continued*)

A Position of septal composite graft on the forehead

B Septal composite graft sutured to the undersurface of the forehead flap

C The forehead flap is sutured back into position

D Outline of incisions for lining hinged flaps and medial triangular flap

E Medial triangular flap mobilized

F Hinged flaps turned in to provide a portion of the linings of the defect medial triangular flap in position

G and H Illustrates the medial triangular flap to prevent notching at the area of junction between the forehead flap and the tip of the nose

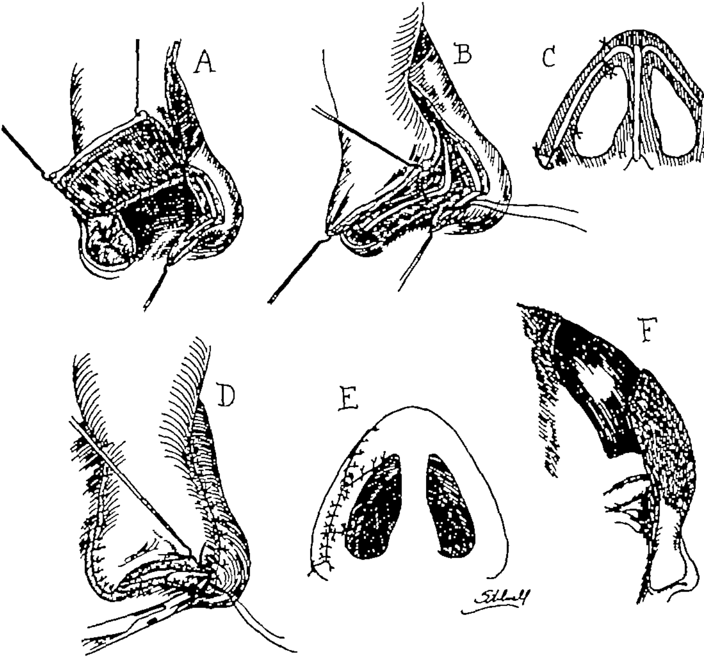


FIG 782. Reconstruction of alar defect by means of septal composite graft and forehead flap (*Continued*)
A, B and C. Illustrates detail of suturing the forehead flap into nasal defect.
D and E. Detail of suture of medial triangular flap
F Appearance of patient at completion of operation. The forehead defect is covered with a free skin graft.

A vertical incision is made through the septum at the junction of the cartilaginous septum with the perpendicular plate of the ethmoid (Fig 788) A flap of cartilage covered on both sides with mucoperichondrium, is thus delimited. This flap receives its blood supply from the mucous membrane which covers the cartilage

PRELIMINARY REDUCTION IN SIZE OF THE REMAINING NASAL STRUCTURES BEFORE NASAL RECONSTRUCTION It is obviously a more simple procedure to reconstruct a small nose than a large nose because of the lesser amount of tissue required. In a large reconstructed nose the nasal tip must have sufficient projection to be in line with the dorsum of the remaining portion and considerable tissue may be required to restore a nose of such size. In such cases, it is advantageous to reduce the size of the remaining portion of the nose in a preliminary operation This is done by a typical

FIG 783 Septal composite graft and forehead flap for reconstruction of the nose.

A. Defect of the lower half of the nose.

B. Result obtained by techniques illustrated in Figures 780 781 and 782.

C. Lateral view of the nasal defect.

D Lateral view of reconstructed nose.

(From J M Converse S *Clin. North America* 39 535, 1959)

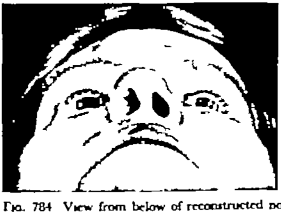


FIG. 784 View from below of reconstructed nose shown in Figure 783 illustrating precise adjustment between the reconstructed ala and the tip of the nose obtained by the use of the triangular median flap (see Fig 782 G and H)

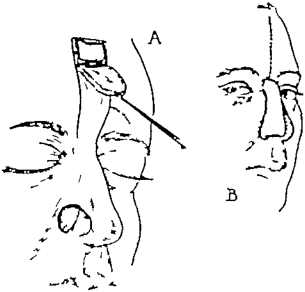


FIG 785 Reconstruction of alar defect by septal composite graft and median forehead flap.

A Insertion of composite septal graft under median forehead flap

B. *Position of median forehead flap after transfer* of the defect. The septal composite graft provides the cartilaginous support and lining of the new ala.

FIG 786 Septal composite graft and median forehead flap for reconstruction of the nose

A Defect of the lower half of the nose

B Result obtained by technique illustrated in Figure 785.

C. Lateral view of the nasal defect

D Lateral view of the reconstructed ala.

corrective rhinoplastic procedure which consists of resecting the hump of the nose thus reducing the projection of the dorsum the procedure is followed by an osteotomy of the lateral nasal walls (Fig 789)

Fig 787 Photograph showing median forehead flap employed in patient shown in Figure 786.

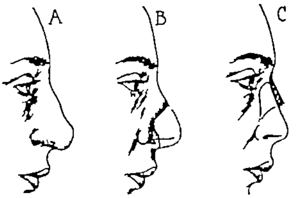


Fig 789 Preliminary reduction of the nasal stump prior to reconstruction of the nose.

A. Size of the nose prior to injury

B. Outline of the large sized nose required to fit the nasal stump

C. Reduction of nasal stump by corrective rhinoplastic procedure permitting the construction of a smaller sized nose.

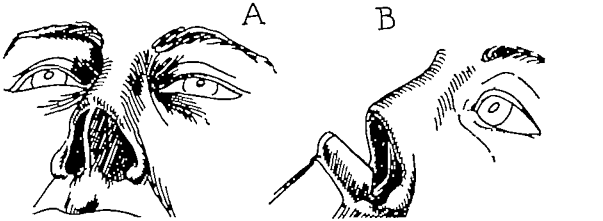


Fig 788. Use of the remaining portion of the septum as support for the reconstructed nose

A. Outline of incisions through the septal cartilage at the junction with the perpendicular plate and the vomer

B. The flap of septal cartilage and mucoperichondrium is swung forward. It will be sutured to the tip of the reconstructed nose.

(After H. D Gillies and D R. Millard, *The Principles and Art of Plastic Surgery* Little, Brown & Co. 1957)

SECONDARY RETOUCHING OF THE RECONSTRUCTED NOSE. Nasal defects repaired by either forehead or distant flaps frequently require additional adjustments such as the trimming of excessive fat or the attaining of further refinement of the alae and columella

Subcutaneous fat usually must be removed from the upper portion of the nose (Fig 790-2) and over the lower portion of the reconstructed nose. The ala is thinned through an incision made along the free margin of the reconstructed ala. The columella also usually requires narrowing: this is achieved by excising a vertically directed ellipse from the middle portion of the columella. The normal columella widens above at the junction with the tip and below at the base these features should be preserved in the reconstructed columella.

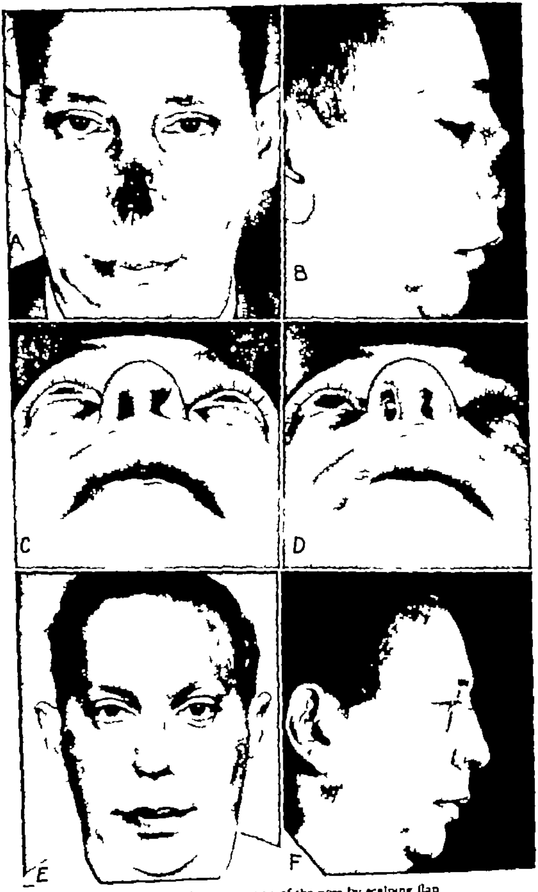


FIG. 700-1 Reconstruction of the nose by scalping flap

A. Appearance of patient after excision of the nose for malignancy.

B. Profile view of nasal defect.

C. View from below of reconstructed tip and nares.

D. Acrylic molds worn in the vestibules of the nares during the first few months after the reconstruction.

E. Full face appearance of patient five months after nasal reconstruction. Secondary repair of the forehead defect has not yet been undertaken.

F. Profile view of the reconstructed nose. Note the satisfactory projection of the tip due to the adequate length of the columella.

(From J. M. Converse. S. Clin. North America, 39:335, 1959.)

MAINTENANCE OF THE PROJECTION OF THE TIP AND THE LENGTH OF THE COLUMELLA IN THE RECONSTRUCTED NOSE. A flap must be of sufficient length to maintain adequate protrusion of the nasal tip When the flap is not of sufficient length the tip of the nose is drawn down by a short columella Secondary correction of this deformity requires sectioning the columella replacing the tip in a position of adequate projection and maintaining this position by an intranasal prosthesis the columella is restored in a later stage by a median or a supraorbital horizontal flap.

CARTILAGE OR BONE GRAFTING FOLLOWING SUBTOTAL NASAL RECONSTRUCTION Some noses, reconstructed by a forehead flap do not require a supporting framework. The transplanted tissue maintains its shape and the new nose retains adequate projection Other reconstructed noses become soft and flattened and require support. Costal cartilage and iliac bone are the materials of choice to supply a framework. Unlike bone cartilage does not require contact with the bony nasal framework to survive, an advantage when the defect involves the nasal bones.

It is preferable to insert the cartilage graft after reconstruction of the soft tissues of the nose, rather than attempt preliminary implantation under the forehead flap

Cartilage or bone grafting should be delayed for a period of at least four months, following the completion of soft tissue reconstruction to permit revascularization and softening of the transplanted tissues.

A vertical incision at the tip of the nose which extends downward through the columella or a butterfly incision at the tip are both satisfactory routes through which to introduce the cartilage or bone graft. The skin is undermined along the dorsum of the new nose with small blunt tipped scissors. A dorsal supporting graft is then introduced into the undermined area. When the tip of the nose requires increased projection a second graft is placed

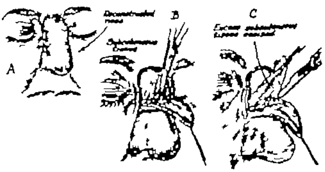


Fig 790-2 See text

into the columella previously undermined to the nasal spine with small blunt-tipped scissors. The second graft placed in the columella rests on the nasal spine and supports the dorsal graft at the tip

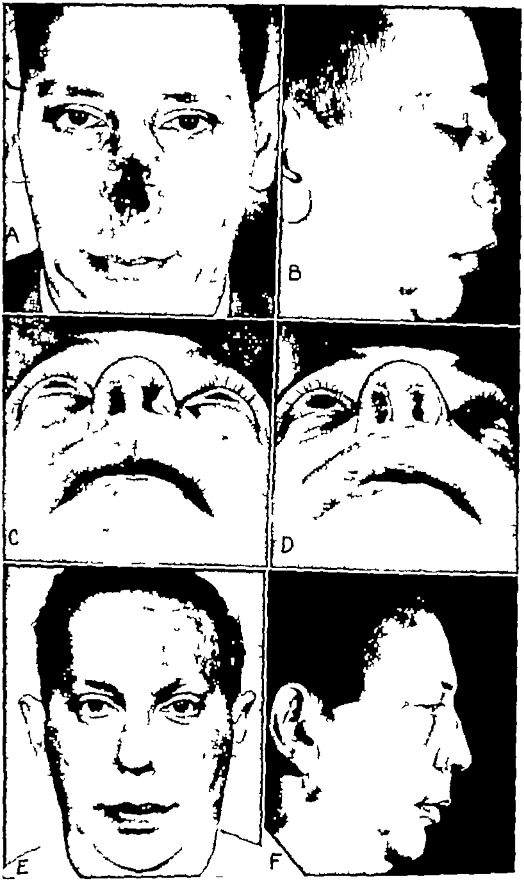
Defects of the Columella

Minor defects of the columella include retrusion of the columella loss of columellar skin alone shortness of the columella or total absence of the columella combined with loss of the septum.

RETRUSION OF THE COLUMELLA. Retrusion of the columella is observed in patients who have suffered septal trauma fractures, or abscess in childhood with subsequent loss of the anterior part of the septal framework Repair consists of transplanting a supporting piece of cartilage or bone through an incision at the side of the columella This technique is shown in Figure 690

In another type of deformity the lower portion of the septal cartilage is covered by a retracted columella which consists of thin cicatricial skin The deformity causes a downward pull of the tip of the nose. The scar is excised in such cases, each side of the columella skin is freely undermined and a retroauricular or a composite skin fat graft from the outer border of the lobe of the ear is transplanted into the defect (Fig 791)

THE SHORT COLUMELLA. The short columella accompanied by a flattened nasal tip occurs more frequently in congenital deformities such as bilateral clefts, than in injuries of traumatic origin, but the principle of reconstruction is similar



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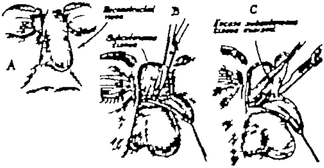

FIG 790-2 See text

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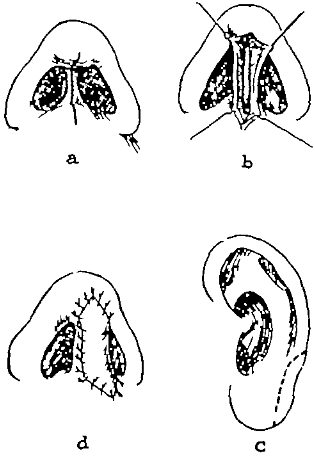


FIG 791 Reconstruction of columella

A and B A vertical incision splits the lower end of the septum.

C A composite graft consisting of skin and fat (Dupertuis) is removed from the outer border of the lobe of the ear

D The composite graft is sutured to fill the defect of the columella.

Elongation of the columella is achieved by the V Y advancement method (Fig 792). A V-shaped incision in the upper lip is extended through the membranous septum to the level of the septal angle (Fig 792*A* *B*). The skin is undermined over the tip and the V-shaped flap is raised and sutured in a new and higher position (Fig 792*C*)

Another variation of the V Y technique is to raise a flap from below each nostril, suturing the flaps in a vertical position after undermining the tip and extending the incision in front of the septum this procedure, however is not suitable for patients with a short upper lip (Fig 793 see also Figs. 667 and 668)

LOSS OF THE COLUMELLA. Complete loss of

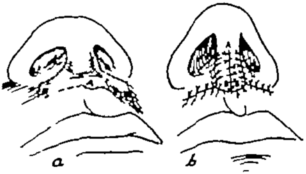


FIG 793 Elongation of the columella and raising the tip of the nose by two flaps of skin from the upper lip.

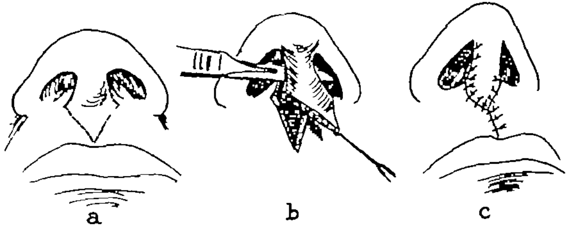


FIG 792

A A V-shaped incision is made below the columella.

B. The incision is carried through the membranous septum and extended to the tip.

C The columella is raised and sutured in its new position.

Fig 794 Reconstruction of columella by median forehead flap
A, B and C Collumellar and alar defect resulting from dog bite.
D E and F Result obtained by use of median forehead flap as shown in Figures 795 and 796.
(Figs. 794 to 796 from V H Kazanjian, Surg Gynec. & Obst., 83 37 1946)

the columella combined with loss of the lower part of the septum is associated with defects of the lip and adjacent tissues It is evident that extensive repair of this type of deformity requires a greater amount of tissue. We have utilized a median forehead flap to supply sufficient skin for the repair of such defects. Figures 794 795 and 796 illustrate the use of this method.

Lengthening the Nose

Shortening the nose results from one of three causes (1) inadequate nasal lining (2) loss of the nasal framework or (3) destruction by burn or other trauma of the cutaneous covering of the nose. The three layers may be involved in injuries which include the full thickness of the nose.

The restoration of an adequate nasal lin

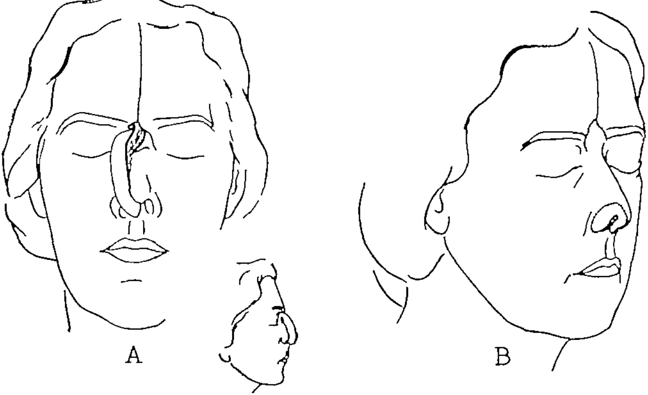


FIG 795 Technique of reconstruction of columella by median forehead flap
A. Median flap inserted into columellar defect
B Shows reconstructed columella and ala.

FIG 796. Photographs of patient shown in Figure 794 The median forehead flap has been sutured into the columellar defect.

ing by means of a forehead flap skin surface placed inward (see Figs. 726 727 and 728) and by skin grafting the nasal cavity using the nasomaxillary epithelial inlay technique (Figs. 721 722 and 723) are procedures which have been discussed previously An additional method consists of turning a hinged flap of nasal tissue into the defect

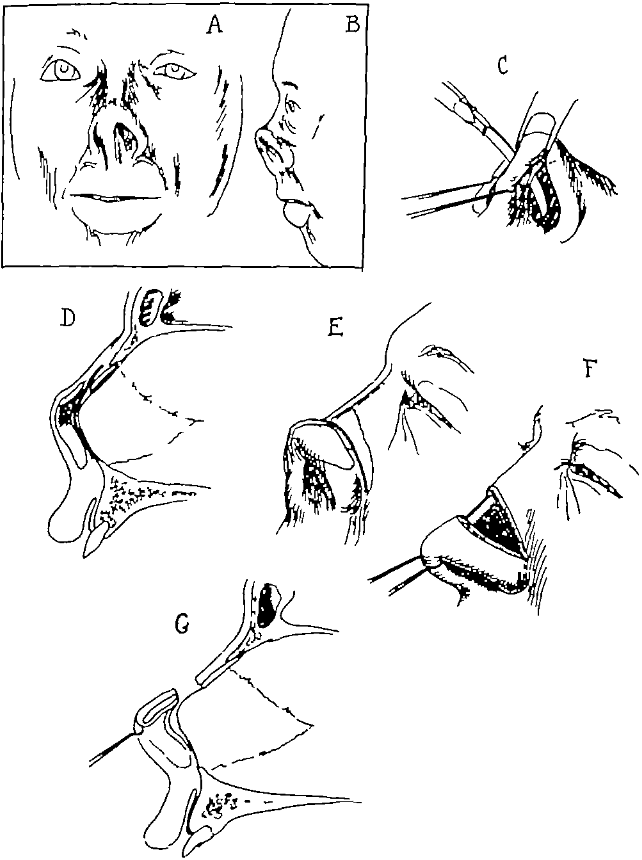


FIG 797 Elongation of the burned nose
A and B. Typical appearance of nose following contracture of the covering soft tissues.
C and D Transfixion incision separating the alar cartilages from the septum.
E. Transverse incision through the soft tissues of the nose above the alar cartilage.
F and G The nasal tip is pulled down into the correct position.

FIG. 798. (*Upper*) This patient had an infection of the nose in childhood following trauma the nose failed to develop as she grew older Photographs show a small nose with a retracted tip and a depressed bridge with considerable stenosis of the left naris. The skin over the nose was soft and healthy The repair of the nose involved three operations In the first operation rib cartilage was used to raise the bridge of the nose Later cartilage was removed from the concha of the ear and through an incision inside the nose the skin of the tip of the nose was undermined freely and the ear cartilage transplanted in two pieces. Ear cartilage was transplanted to the tip of the nose, and in addition, the stenosis of the left naris was corrected by excising the scar tissue and transplanting a thin graft, using a dental compound mold as a carrier

(*Lower*) Postoperative photographs of same patient.

produced by the freeing of the lower portion of the nose from its retracted position (Figs. 776 and 777) This hinged flap method can be employed in combination with a forehead flap *to provide a covering in* cases where the nose has become shortened through loss of tissue at the dorsum The tip of the nose is retracted upward the deformity consisting of a saddle nose and also a shortened nose. The nasal structures are freed by a transverse incision which permits the release of the telescoped nasal structures and the replacing of the tip in a position compatible with normal nasal length (Figs 776 and 777) The hinged flap is provided by tissue from the upper portion of the nose turned down and sutured to the edges of the defect. A forehead flap is then used to restore the cutaneous covering of the nose.

The striking deformity in burned noses is the upward retraction of the alae of the nose a condition quite marked in some cases (Fig 797*A* *B*) The tip and alar borders are replaced in their anatomical positions in a preliminary operation. The tip structures are separated from the septum by a transfixion incision similar to that employed in corrective nasal plastic operations (Fig 797*C* *D*) the lateral wall of the nose is incised transversely on each side (Fig 797*E*) and the tip is pulled downward (Fig 797*F* to *G*) This results in a full thickness defect of the nose above the tip in the region of the lateral cartilages (Fig 797*F* *G*) Recurrence of upward retraction is prevented by the employment of a prosthetic appliance which maintains the downward position of the tip structures during the intervening period between the preliminary procedure and the later reconstruction by a forehead flap or a flap from another area.

The upward retraction is less marked in other cases and the alar borders may be rolled downward after being freed by skin incision or reconstituted by means of turned *down hinge-flaps*

Nasal shortening may also be due to loss of the osteocartilaginous framework only for both the nasal lining and the covering skin are adequate Nasal length can be improved by bone and cartilage grafting often performed in stages to avoid excessive tension on the skin

Nasal shortening is also seen in developmental malformations following injury in early childhood These cases frequently show an accompanying maldevelopment of the maxilla the deformity being nasomaxillary rather than one which involves the nose alone Treatment should consist not only of lengthening the nose but also of building up the contour of the recessed maxilla by onlay bone grafts (see Fig 988 Chapter 24)

One can gradually elongate the tip in certain types of short noses and improve the contour of the bridge achieving a more normal appearance by the addition of bone or cartilage at different intervals This procedure is indicated only when the skin and mucosa of the nose are healthy and free from adherent scars. The amount of transplant that can be accommodated depends upon the elasticity of the skin covering

A section of conchal cartilage is removed a considerable quantity may be obtained without causing appreciable change in the shape of the auricle A vestibular incision near the apex of the nose and the skin of the tip of the nose is undermined one or two thicknesses of cartilage of suitable size are then inserted Additional cartilage is transplanted (Fig 798) when the skin of the tip of the nose becomes more pliable.

23

DEFORMITIES OF THE SOFT TISSUES OF THE FACE

Deformities of the soft tissues of the forehead and scalp the orbital regions and the nose are discussed elsewhere in the text (see Chapters 20 21 and 22) The soft tissues over the other regions of the facial framework the lips cheeks and cervical region are described in this chapter These include the subcutaneous tissues, containing the muscles of facial expression and also the skin which covers the lips and the cheeks.

The external maxillary or facial artery a branch of the external carotid, supplies the major portion of the blood to the soft tissues of the face The external maxillary artery can be palpated immediately anterior to the masseter muscle as it crosses the lower border of the body of the mandible The artery courses upward and forward to a point about 2 cm. lateral to the corner of the mouth where superior and inferior labial branches supply the lips.

Another branch the lateral nasal artery supplies the ala of the nose, facial muscles and alar cartilages The angular artery continues upward on the face above the lateral nasal supplying the angular head of the quadratus labii superioris muscle and anastomoses with the lateral nasal and nasal and palpebral branches of the ophthalmic artery

The tortuous course of the external maxillary artery is in marked contrast to the relatively direct route followed by the anterior facial vein which is located just posterior to the artery

The facial nerve, essential to the function of the superficial facial musculature of expression enters the parotid gland after leaving the stylomastoid foramen forms a plexus in the substance of the gland and then divides into terminal branches these radiate from the borders of the gland like digits of an outstretched hand, anastomosing with each other and with branches of the trigeminal nerve The facial nerve filaments enter the facial muscles on their deep surfaces, except where the muscles are two layers in thickness the nerve filaments penetrate the muscles of this deeper layer on their superficial surface Further considerations dealing with the anatomy of the facial nerve are described in Chapter 27

The cheeks may be described as consisting of anterior and posterior portions the junction between the two portions is located along a line which is parallel to the anterior border of the masseter muscle (Fig 799). The anterior portion of the cheek is mobile through the action of the superficial facial musculature The parotid-masseteric region overlies the masseter muscle and the parotid gland structures which are covered by the parotid masseteric fascia This area is relatively immobile but is subjected to movement due to contraction of the masseter muscle and the excursions of the mandible

Deformities of the cheek may be due to

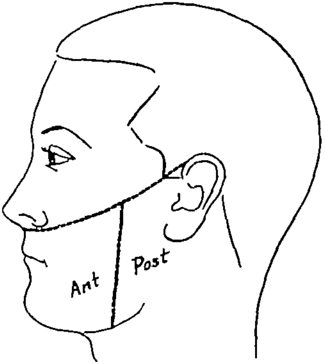


FIG 799 Division of the soft tissues of the lower third of the face into two portions, anterior and posterior delimited by a vertical line parallel to the anterior border of the masseter muscle.

scars and contractures of the skin or mucosa full thickness loss of the lip or cheek or scars, contractures or soft tissue loss in association with defects or malposition of the underlying bony framework

Adequate early treatment minimizes late deformities. Such treatment is initiated by primary or late primary suture combined with early immobilization of fractured bones, especially in cases which involve loss of teeth and alveolar bone A temporary supporting foundation for reconstruction of the lips and cheeks is essential as a preliminary procedure such a support may be provided by a dental splint or denture which serves as a framework for the reconstructed tissues (see Chapters 4 and 6).

The reconstructive procedures in full thickness loss of soft tissues associated with loss of bone include the restoration of normal contour by readjustment of displaced tissue and replacement of missing bone later restoration by bone grafts in the event of the absence of a portion of the mandible and finally restoration of a functional alveolar process by reconstruction of a new buccal sulcus in order that a permanent prosthesis may be worn (see Chapter 25)

Full thickness soft tissue loss of the lower lip and bone defects of the mandible are intimately associated such defects are considered concomitantly in Chapter 24

DEFORMITIES OF THE UPPER LIP

Superficial Deformities

Local Flaps

Simple linear scars which pull the vermilion border of the lip out of line or result in notching are corrected by excision of the scar and resuturing of the wound. Z flaps are especially useful in repairing such scars to neutralize the linear contraction of the scar (Fig 800)

Loss of skin of the upper lip may result in severe scar contracture and distortion of the lip The extent of tissue loss the true defect is visible after the scar is resected The type of repair depends on the location of the defect and the amount of tissue loss. In reparative procedures local skin flaps should be used when possible. A rectangular skin flap from the nasolabial fold is preferred for laterally placed defects (Fig 801) the secondary defect is closed by direct approximation without tension, and without leaving a conspicuous scar (Fig 802) Flaps may be taken from the nasolabial areas on both sides if the skin loss is bilateral, or when the skin of the entire lip requires replacement.

Loss of skin in the region of the corner of the mouth resulting in distortion is replaced by mobilizing flaps from the lower lip or the cheek as shown in Figure 803

When scars involve the side of the lips, causing an upward or downward distortion of the corner of the mouth, a triangular shaped flap is taken from the area of excess tissue and transposed to cover the raw area

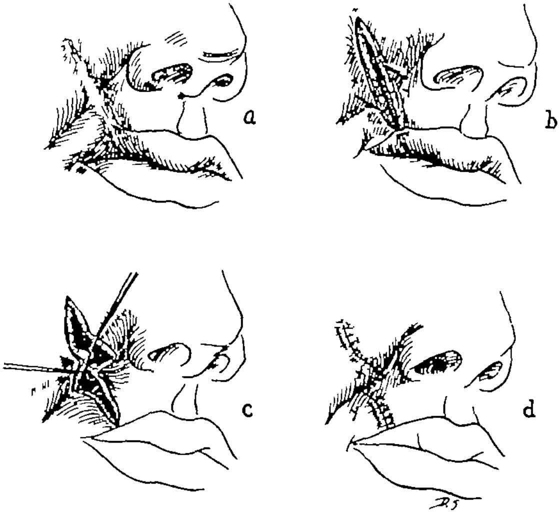


FIG 800 Z-flaps utilized to break a straight line of suture extending across a natural fold

A Ectropion of the upper lip and distortion resulting from a vertical scar extending through the nasolabial fold.

B. Excision of the scar Incisions X and Y outline the Z flaps.

C. The Z-flaps are transposed.

D The wound has been sutured. The straight line continuity has been broken and the normal contour of the region has been restored.

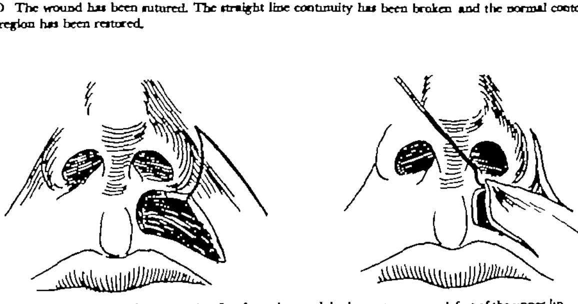


FIG 801 Example of transposition flap from the nasolabial area to cover a defect of the upper lip

A B

Fig 802

A. Photograph showing conspicuous tattooed area of the upper lip from automobile accident.

B. The tattooed area has been excised. A nasolabial skin flap was brought down to cover the defect following excision of the discolored area in the manner illustrated in Figure 801

(From V H. Kazanjian, Tr Am. Acad. of Ophth. and Otol., 38 295 1935)

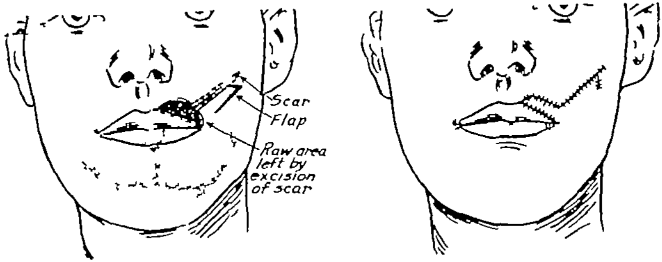


Fig 803 Repair of ectropion of upper lip with a transposed cheek flap The nasolabial flap could not be used in this case because the blood supply was jeopardized by scar tissue.

after the corner of the mouth has been returned to its normal position (Figures 804 and 805)

Skin Grafts

Full thickness skin grafts from the postauricular or supraclavicular areas are indicated for small skin defects in the median portion of the lip and for large defects when local flaps are not available, as when the surrounding area is also badly scarred from the effect of burns (Fig 806)

In repairing upper lip skin defects in male children it should be remembered that the skin graft may become conspicuous in later years because the graft remains hairless adjacent hair bearing skin should therefore be employed when possible.

Distant Flaps

When the defect involves the lip and other structures such as the side of the nose or the neck skin is transposed from more distant areas A tubed pedicled flap replacing a defect produced by the excision of a hypertrophic scar is illustrated in Fig 807

Full Thickness Defects of the Upper Lip

Deformities due to full thickness loss of lip tissue resulting from trauma as in gunshot wounds differ from deformities due to the excision of malignant tissue In the latter a section of definite size is removed and the repair is often completed in the same operation The tissue loss in wounds due to trauma is often not as great as the gap may indicate due to traction exerted

A B

Fig. 804

A. Outline of incision for transposition of skin flap in repair of the upper lip and corner of the mouth.
B. Transposition of skin flap from the lower to the upper lip.

A B

Fig. 805

A. Photograph showing distortion of the upper lip and corner of the mouth.
B. Appearance of the patient following the repair of the upper lip by the technique illustrated in Figure 804

by the surrounding tissues, particularly if treatment has been delayed. Radiating scar lines in traumatic deformities of the soft tissues are not uncommon in multiple lacerations and at the exit wound of a missile.

Adjacent deep scars of the lips and cheeks often jeopardize the success of the reconstructive operation because ... with the blood supply th... procedure may thus require modification and a *simple procedure becomes* a more complicated one. It may be necessary to excise the scar tissue and delay the main operation until healing has occurred and vascularization of the area has improved.

In fu... s defects of lips or cheeks, althou... *tissue is displaced* and deprived ... l support due to loss of

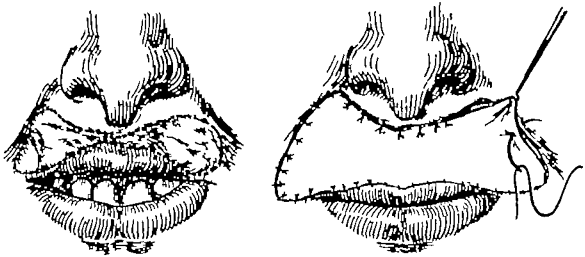


FIG. 806 Full thickness skin graft to repair burn contracture of upper lip is excised as far laterally as the nasolabial folds. A full thickness skin graft covers the defect. Normal contour of the upper lip has been restored.

FIG. 807 Hypertrophic scars resulting from gasoline burn incurred in an automobile accident.

A. Hypertrophic scars of the right side of the face and neck loss of right ear

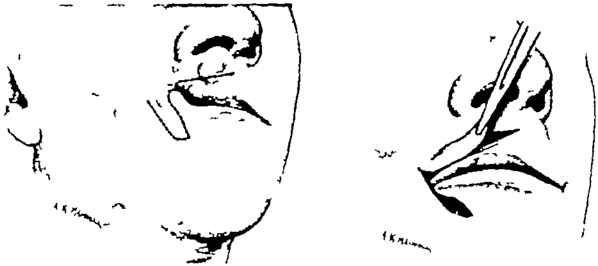
B Scars of the left side of the nose, lips and corner of the mouth.

C. Result obtained by replacement of defective skin by transplantation of a tubed pedicled flap.

D Tubed pedicled flap raised in the left flank.

E. Transfer of the lower end of the tubed pedicled flap to the base of the neck.

F Transfer of tubed pedicled flap to corner of the mouth.



A B

FIG 804

A. Outline of incision for transposition of skin flap in repair of the upper lip and corner of the mouth.
B. Transposition of skin flap from the lower to the upper lip.

A B

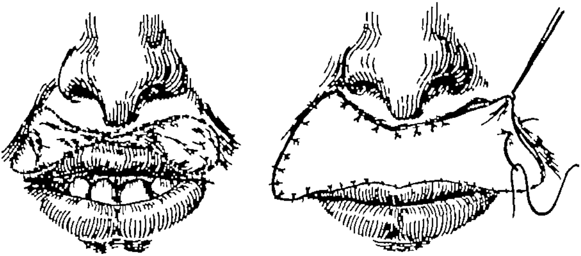
FIG 805

A. Photograph showing distortion of the upper lip and corner of the mouth.
B. Appearance of the patient following the repair of the upper lip by the technique illustrated in Figure 804

by the surrounding tissues, particularly if treatment has been delayed. Radiating scar lines in traumatic deformities of the soft tissues are not uncommon in multiple lacerations and at the exit wound of a missile

Adjacent deep scars of the lips and cheeks often jeopardize the success of the reconstructive operation because they interfere with the blood supply the plan of surgical procedure may thus require modification and a simple procedure becomes a more complicated one. It may be necessary to excise the scar tissue and delay the main operation until healing has occurred and vascularization of the area has improved.

In full thickness defects of lips or cheeks, although the soft tissue is displaced and deprived of its normal support due to loss of



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A B C

D E F

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D Tubed pedicled flap raised in the left flank.

E. Transfer of the lower end of the tubed pedicled flap to the base of the neck.

F Transfer of tubed pedicled flap to corner of the mouth.

alveolar bone and teeth, and retraction by the pull of the surrounding tissues sufficient mucosa and skin often remain in the neighboring tissues to allow for reconstruction The mucosa of *the oral cavity has an inherent degree of elasticity* and liberal use can be made of the remaining mucosa to provide a lining for the part to be reconstructed Local flaps of mucosa are usually adequate for repair

In reconstructing defects of the lower lip and mandible in young patients *the available* surrounding tissue is not as abundant as in older patients who undergo reconstruction for defects resulting from excisional surgery for malignancy This inconvenience in the younger patient is counterbalanced by the fact that the tissues are more vascular and heal more readily

The importance of avoiding raw areas in reconstructive operations of the lips was realized by a number of surgeons Serre (1842) claimed priority in emphasizing the principle of providing a *lining* in *all* reconstruction procedures of the lip

When it is necessary to employ a local *flap* to restore the inner lining of a reconstructed lip in male patients the operative procedure should be planned to avoid placing *hair-bearing* skin in *the oral cavity* Flaps of non hair bearing skin are available lateral to the nasolabial fold. Such precautions are not necessary *in female patients* and in male patients who have previously been subjected to radiation therapy and whose hair follicles have been *destroyed* over the area available for the flap Scar tissue, if soft and well vascularized and devoid of hair *follicles, may occasionally be* employed as a turned in hinge flap to restore the inner tissues.

The following principles are of assistance in planning reconstruction of the lip (1) The remaining portions of the injured lip *should be utilized* (2) *If this is not possible* tissue should be borrowed from the opposing lip (3) When sufficient lip tissue is not *available* flaps are rotated from the sides of the defect. (4) The design of such flaps is often dictated by the presence of pre-existing scars It may be necessary to resort to the use of distant flaps. There is no advantage *in using distant flaps* that shrink, curl inward or retract downward owing to a lack of muscular action *For this reason every effort should be made to utilize local flaps*

Median Defects of the Upper Lip

Small defects of the median portion of the upper *lip* are repaired by excising the wound edges and closing the V-shaped defect produced *by* direct approximation. A straight line of approximation between the wound edges must be avoided, as in all operations upon the lip *healing of the* straight line may result in retraction of the vermilion border a Z plastic procedure avoids *the straight line* (see *Fig 848*).

Moderate sized median defects of the upper lip may be closed by direct advancement of the remaining portions of the lip the advancement is facilitated by the excision of a Bürow (1838) triangle from the upper portion of the nasolabial fold (Fig 808)

We prefer to transpose a quadrilateral flap *from each side of the defect to correct* a median deformity This is a modification of the flap advocated by Blasius (1839) and *by von Bruns (1859)* A diagonal full thickness incision is made along the base of the nose to the nasolabial groove, and a slightly *curved vertical incision is extended* below the corner of the mouth (Fig 809) The two full thickness flaps are mobilized and sutured *together* (Figs. 809 and 810) In this type of flap the base of the pedicle is narrower than the distal end and the acute angle at the apex permits approximation of the tissues of the donor area at the side of the nose the rich blood supply of the region permits its use although the pedicle is narrow The flaps should be freed by wide incision of the mucosal attachments in the oral vestibule Careful measurement is

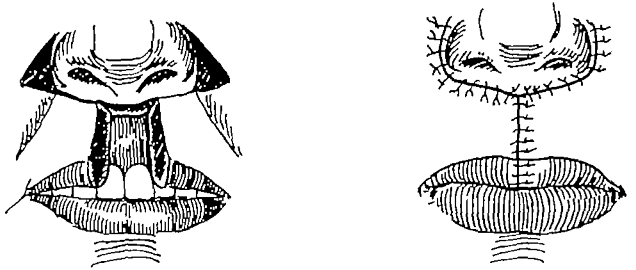

FIG 808 The advancement of the lateral portions of the lip is facilitated by the excision of a Bürow triangle from each nasolabial area in order to close a median defect of the upper lip.

FIG 809 Lines of incision extending along the base of the nose to the nasolabial groove and downward below the corner of the mouth on each side, thus forming two quadrilateral full thickness flaps used in repair of median defect of upper lip (von Bruns)

necessary to estimate the proper size of the flap excess width is preferable, for scrimping results in a short upper lip Figure 811 shows a variation of the flaps described above A modification of this type of flap advocated by Gillies (1957) is shown in Fig 812

The Abbé Operation (1898)

For moderately sized defects of the upper lip a triangular full thickness flap is taken from the median portion of the lower lip (Figs. 813 and 814) The flap is left attached to a pedicle near the vermilion border for the labial artery close to the labial mucosa provides an adequate blood supply The flap is then swung upward to fit into the defect of the upper lip The pedicle is sectioned and the mucocutaneous line re established after two weeks. A prosthetic mold is placed in the mouth to support the lip if bone is missing and should be retained until long after the sutures are removed the newly repaired lip will contract unless intraoral support is maintained at all times. The authors have observed cases in which

A B

Fig 810

A. Median defect of upper lip.

B. Photograph of face showing repaired upper lip following the approximation of the two quadilateral flaps according to the technique illustrated in Figure 809.

difficulty was experienced in replacing the support even after only five or six hours Figures 813 and 814 show various stages of the Abbé operation

Abbé Operation Combined with Transposed Flaps

In larger median defects of the upper lip particularly when tissue in the lower lip is abundant, the Abbé median flap procedure may be employed in conjunction with the transposition flaps previously described (Fig 815) The Abbé flap provides additional needed tissue and avoids undue tension upon the reconstructed upper li

Lar the Abbé Fl

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A simil Abbé fla signed whe is requir outline of t s down

upper border of the fat pad of the chin and laterally on each side of it (Fig 817) If the lower lip is formed of abundant loose tissue, large flaps can be removed by this method the secondary defect is thus closed successfully without too much tension upon the lip

Lateral Defects of the Upper Lip

When one side of the lip has been destroyed the design of the operative procedure is determined by the amount of lip tissue which remains and the scarred tissues which surround the defect. A full thickness lip flap of the Abbé type in minor defects involving the border of the lip may not be required for a nasolabial flap provides a satisfactory repair (Fig 818)

Lateral Flaps

Large defe e side of the lip may volve the o-thirds of the lip such co e uninjured section

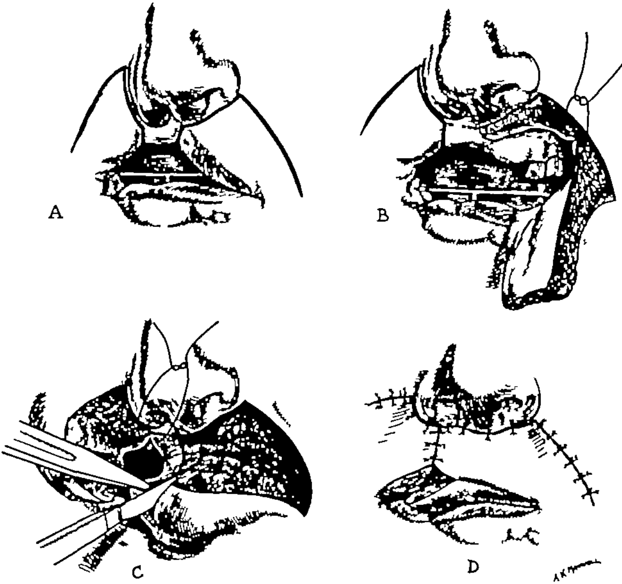

Fig 811

A. Outline of quadilateral flaps for correction of median lip defect.

B One flap is turned downward.

C. The mucosa is sutured.

D The two flaps are approximated and the lip line is extended.

Fig 812. Repair of large median defect by nasolabial flaps

A. Outline of flaps (fan flaps, Gillies)

B. After the transposition of the nasolabial flaps the closure of the secondary defect at the angle of the mouth is facilitated by the transposition of the two flaps X and Y

A B

FIG. 810

A. Median defect of upper lip.

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Variations of the Abbé Flap

The Abbé flap may be split in its distal portion to provide tissue for the repair of a bilateral defect of the upper lip (Fig 816)

A similar bifid type Abbé flap is designed when a large flap is required. The outline of the flap extends down to the *upper border of the fat pad of the chin* and laterally on each side of it (Fig 817) If the lower lip is formed of abundant loose tissue large flaps can be removed by this method the secondary defect is thus closed successfully without too much tension upon the lip

Lateral Defects of the Upper Lip

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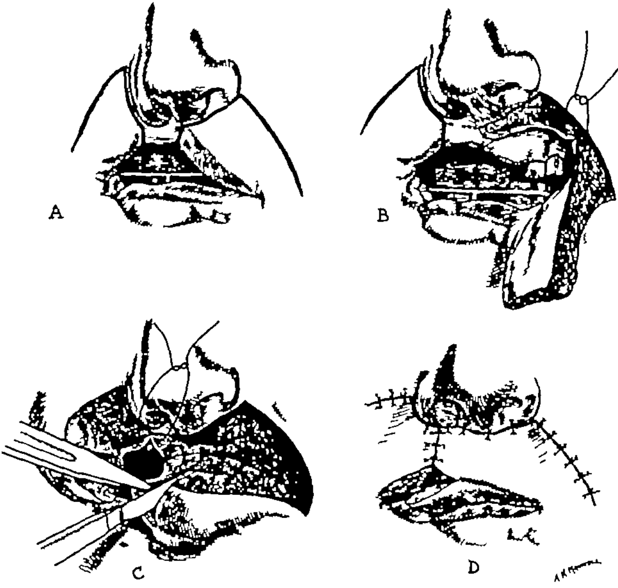
Lateral Flaps

Large defects on the side of the lip may involve the lateral two-thirds of the lip. In such conditions the uninjured section



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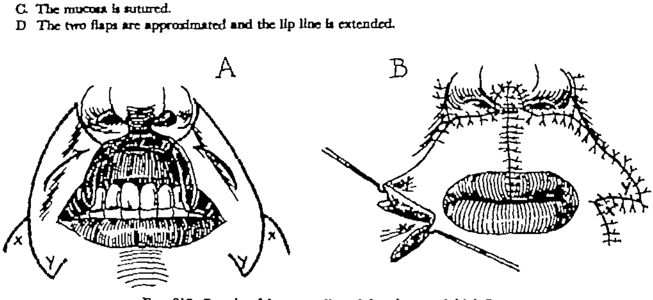


Fig 812. Repair of large median defect by nasolabial flaps

A. Outline of flaps (fan flaps, Gillies)

B. After the transposition of the nasolabial flaps the closure of the secondary defect at the angle of the mouth is facilitated by the transposition of the two flaps X and Y

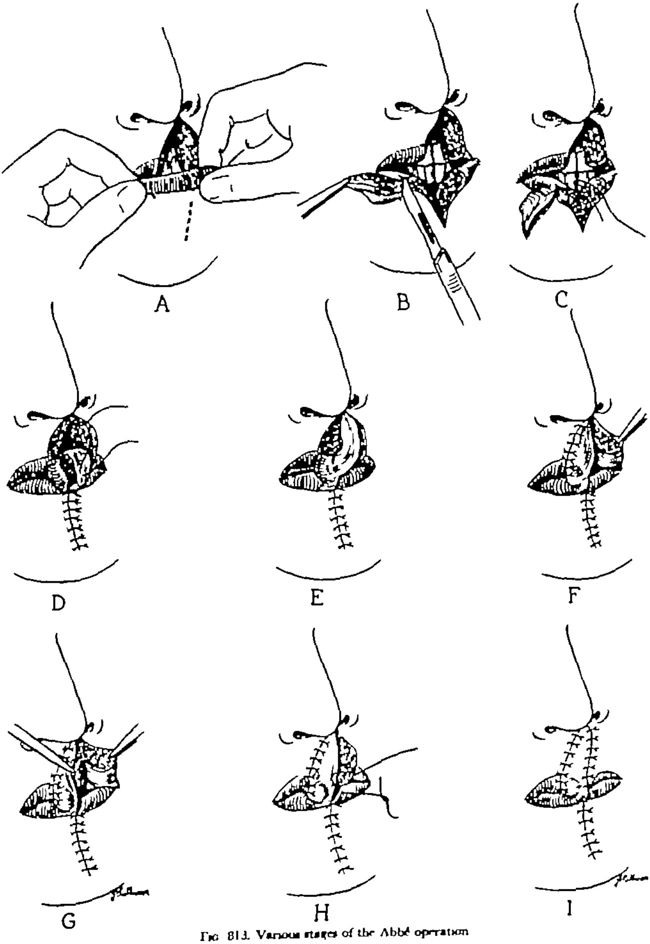


Fig. 813. Various stages of the Abbé operation

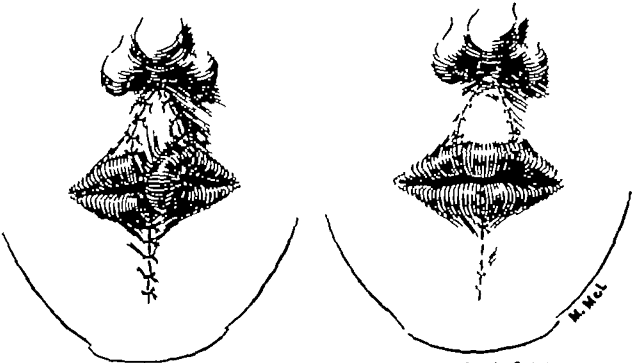


FIG 814 Abbé operation second stage. The lips are separated two weeks after the first stage.

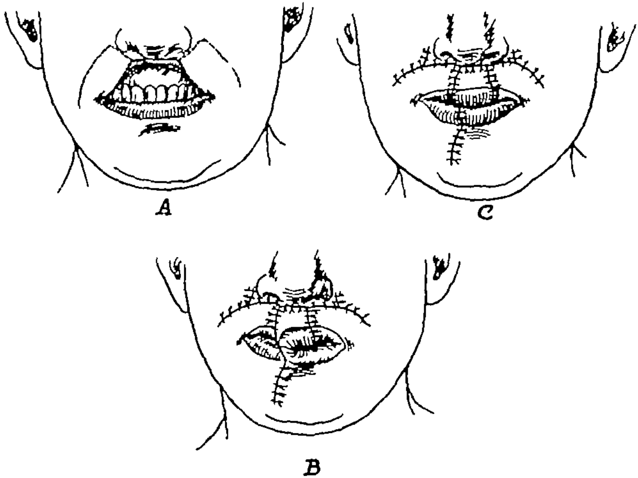


FIG 815. Modified Abbé technique for repair of upper lip
A. Outline of incision for bilateral rectangular flaps.
B. A square flap from the lower lip is raised to supply the median portion of the upper lip.
C. Completion of modified Abbé technique.

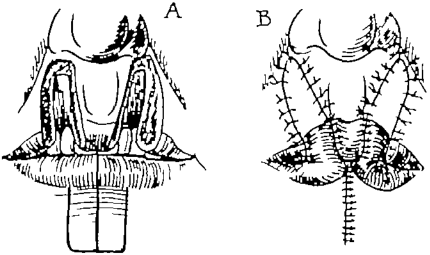


FIG 816 Modified Abbé operation
A. A rectangular Abbé flap is split into two halves.
B. The two tongues of the flap are employed to repair a bilateral full thickness defect of the upper lip.

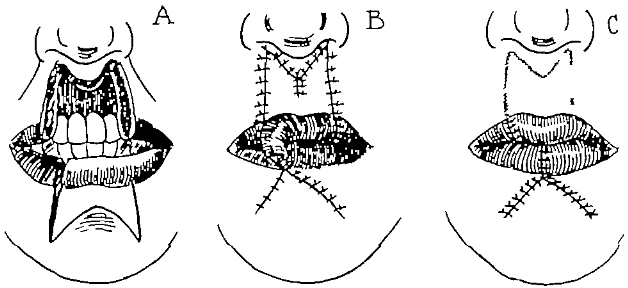


FIG 817 Modified Abbé operation
A. Prong-shaped Abbé flap prepared for repair of a median defect of the upper lip.
B. Aspect of flap after transfer
C. Operation completed.

of the upper lip can usually be utilized through a diagonal incision from the median edge of the lip tissue toward the side of the nose and a wide incision which curves downward laterally into the nasolabial fold (Figs 819 and 820) and extends to a point below the level of the corner of the mouth An additional rectangular flap from the opposite side of the lower lip is transposed to form the outer [illegible] of the upper lip and is sutured t[illegible]

the opposite side Closing the secondary defects caused by mobilization of the flaps is usually achieved with little difficulty due to the looseness of the cheek tissues.

This is a satisfactory operation which utilizes the basic principles of the procedures described by Sedillot (1848) and Denonvilliers (1851)

[illegible] Thickness Cheek Flaps

[illegible] is sometimes borrowed to fill the [illegible] A rectangular full thickness

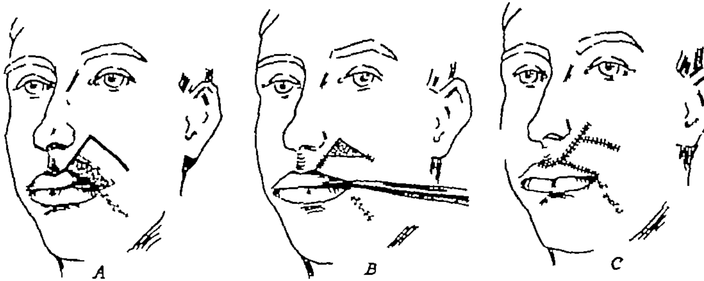


FIG 818

A. Diagram showing lateral defect of the lip and line of incision for nasolabial flap.

B. The nasolabial flap is lowered and sutured and the mucosa of the upper lip is stretched to the corner of the mouth.

C. The repair completed.

FIG 819 Reconstruction of the upper lip by lateral flaps

A. The lines of incision outlining lateral flaps in the repair of the upper lip

B. The flaps are approximated and sutured.

C. The edges of the secondary defects are sutured.

flap is outlined with the base of the flap at the corner of the mouth and the lower portion of the nasolabial fold (Figs. 821 and 822) The flap is rotated almost 180 degrees and sutured to the border of the lip defect on the opposite side the secondary defect is closed without difficulty Precautions are necessary to avoid sectioning Stensen's duct. The distortion of the corner of the mouth which is due to the rotation of the flap is corrected at a later date.

The Ferris Smith Technique (1942)

The procedure advocated by Ferris Smith consists of mobilizing two delayed skin flaps (Fig 823) a short horizontal flap taken from the side of the defect, and a long vertical flap which extends from the distal end of the horizontal flap downward toward the neck The horizontal flap is raised turned back skin surface inward, and hinged on the mucosa to form the inner lip surface The long vertical flap is rotated about 90

A B

Fig. 820 Photographs showing reconstruction of the upper lip by the technique shown in Figure 819

A. This patient also suffered the loss of a large portion of the maxilla. The prosthesis shown in the figure acts as a supporting framework for the reconstructed soft tissues and the nose.

B. Postoperative photograph.

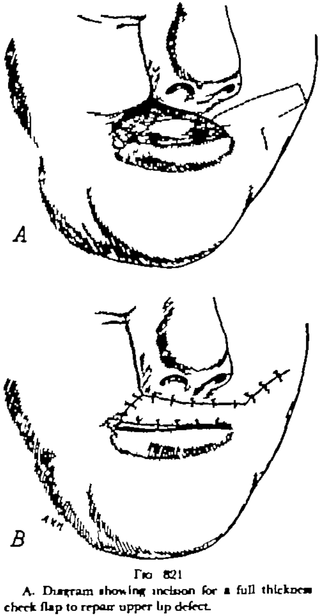


Fig 821

A. Diagram showing incision for a full thickness cheek flap to repair upper lip defect.

B. The flap transposed and sutured

degrees to cover the donor area of the horizontal flap, and to form the new outer lip surface.

The presence of hair follicles in this flap is an inconvenience they often persist even though measures are taken for their eradication

The viability of the horizontal flap must be preserved Since the blood supply is from the hinge formed by the edge of the mucosa, all cicatricial avascular tissue must be excised and the mucosa and skin at the medial end of the flap carefully approximated in a preliminary step

Abbé-Estlander Operation

This procedure utilizes the Abbé principle of employing *a flap from the lower lip* to repair the upper lip it is the reverse procedure of the Estlander operation (1877) for repairing a lateral defect of the lower lip by a flap from the upper lip The procedure is useful in moderate-size defects of the upper lip near the corner of the mouth and consists of rotating a triangular-shaped flap from the side of the lower lip upward to cover the defect (Fig 824) The blood supply is from the labial artery A roundness at the corner of the mouth is corrected in a secondary operation

Variation of the Abbé Estlander Flap

A modification of the Abbé Estlander flap may be employed to repair defects involving

A B

Fig 822

A. Photograph showing defect previous to operation. The scar lines on the face were excised before the full thickness cheek flap operation.

B. Photograph following operation illustrated in Figure 821

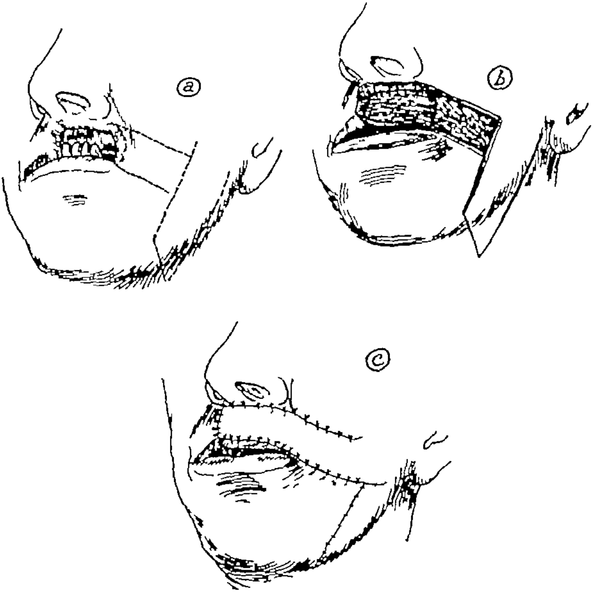


Fig 823. Ferris Smith method for repair of upper lip defect

A. Lines of incision for delayed flaps.

B. The horizontal flap is turned in and sutured to form the inner surface of the lip.

C. Vertical flap is raised and sutured.

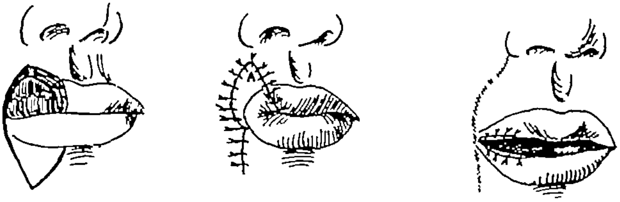


Fig 824 The Abbé Estlander operation a triangular section of the lower lip is shifted to repair a defect of the lateral portion of the upper lip Elongation of the mouth is required as a secondary procedure (see Fig 874)

the upper portion of the lateral aspect of the upper lip The scar tissue which causes the upward contraction of the lip and outward displacement of the base of the ala is excised. The resulting defect involves only the upper portion of the lateral aspect of *the lip the lower portion of the lip and* the vermilion border do not require replacement.

In repairing such a defect with a large Abbé Estlander flap the resulting postoperative tension upon the lower lip is greatest at the vermilion border A variation of the Abbé Estlander flap permits the full utilization of the remaining vermilion border of the upper lip thus avoiding postoperative tightness of the lower lip (Fig 825)

Reconstruction of the defect is initiated by an incision through the vermilion border as shown in Figure 825*A* The incision is made at a distance of approximately 1 cm. from the medial border of the defect to break the straight line extending through the lip The vermilion border flap is tubed (Fig 825*B* *C*) The flap from the lower lip *is outlined and incised (Fig 825D E F)* avoiding the fat pad of the chin. A mucosal vestibular flap is raised medially to facilitate subsequent advancement of the flap (Fig 825*D*) An additional mucosal vestibular flap is raised to provide sufficient lining for the Abbé Estlander flap as illustrated in Figure 825*E* and *F* and the flap from the lower lip is transferred to the defect in the upper lip (Figs. 825*G* and 826 *H I*) When the anterior portion of the floor of the nose is missing, the mucosa is sutured to the skin along the upper margin of the flap to form a new rim to the nasal *floor (Fig 826I J)* The defect in the lower lip is closed by direct approximation. and the edges of the Abbé Estlander flap are sutured to the edges of the upper lip defect (Fig 826*H I J*)

Two or three weeks later the flap is incised in a second stage operation as outlined in Figure 826K The tubed vermillion border of the upper lip is opened and replaced, and the remaining portion of the Abbé-Estlander flap is fitted into the lower lip (Figs. 826*L M*)

Complete Loss of the Upper Lip

The tissue required for repair can be borrowed from the surrounding tissues and from the opposing lip when the entire lip is destroyed. The muscular function of the reconstructed lip is derived from the contraction of superficial facial muscle fibers. *The problem of providing* an adequate quantity of tissue to reconstruct the upper lip can be solved by one of the following methods.

Lateral Flaps

When the tissue situated laterally to the upper lip is available and *the lower lip is*

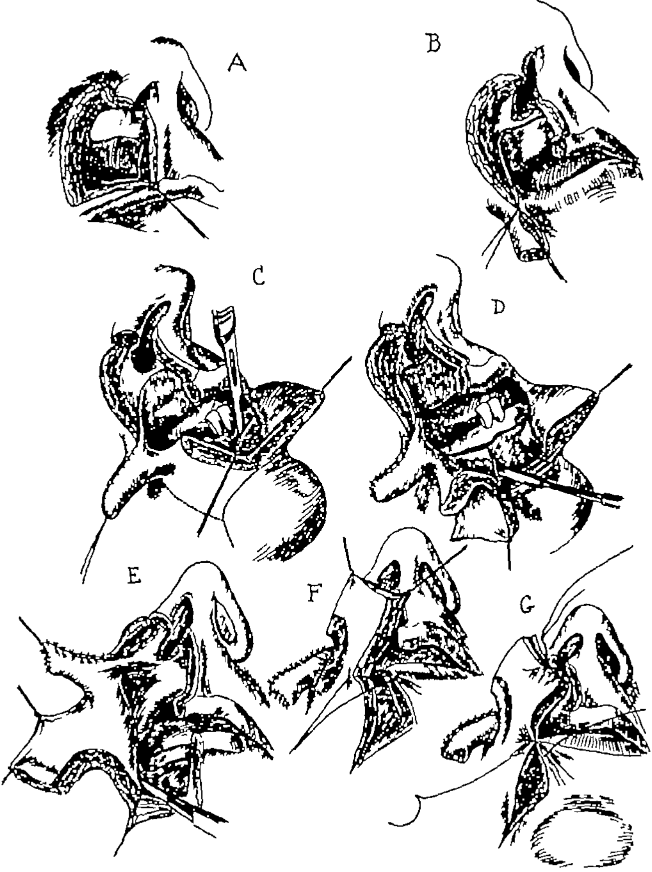


Fig 825. Modified Abbé-Estlander operation

A. Defect in the upper lip and anterior portion of the floor of the nose.

B. Bone is resected from the border of the pyriform aperture. The line of incision in the vermilion border is indicated by a dotted line.

C. The vermilion border flap is tubulated.

D The outline of the Abbé-Estlander flap in the lower lip is indicated by a dotted line. An incision has been made through the lower lip, and a mucosal flap from the lower portion of the oral vestibule on the left side is being raised.

E. The Abbé-Estlander flap has been cut and an additional mucosal flap from the lower vestibule on the right side is raised to furnish sufficient lining to the flap.

F The tissues are retracted demonstrating the Abbé Estlander flap

G Transfer of the lower lip flap to the upper lip defect.

(Continued in Fig 826)

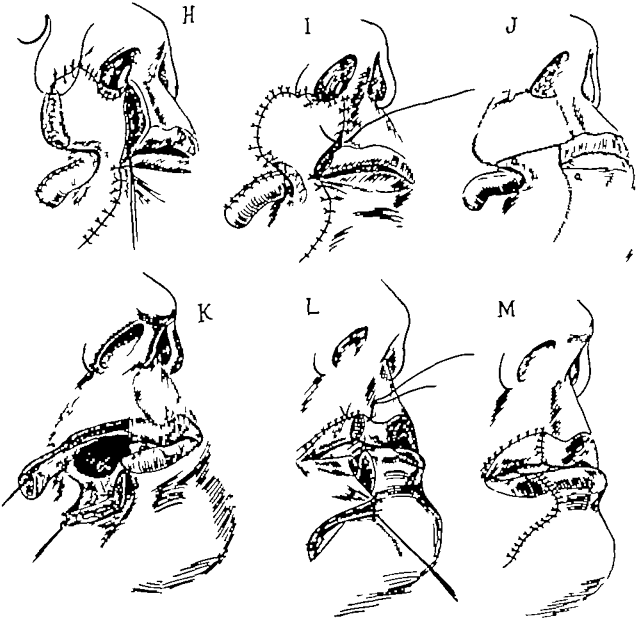


FIG 826 Modified Abbé-Estlander operation (*Continued*)

H. The mucosa is sutured to the skin along the upper margin of the Abbé-Estlander flap. Closure of the lower lip defect is started.

I The edges of the Abbé Estlander flap are sutured to the edges of the defect.

J Suturing is being completed.

K. In a second stage operation two to three weeks later the flap is incised along the dotted line indicated on the drawing

L. The tubulated upper vermilion flap is incised and opened. The remaining portion of the Abbé Estlander flap comprising the vermilion border is ready for replacement in the lower lip

M. Suturing of the upper vermilion border flap is completed. The lower lip flap is prepared for suture

N The second stage operation is completed.

intact full thickness nasolabial flaps combined with an Abbé flap from the lower lip is the method of choice (see Fig 815)

Another technique is to utilize rectangular full thickness flaps rotated from the side of the lower lip (Fig 827) This technique supplies an adequate amount of tissue particularly in older individuals in whom the looseness of the tissues facilitates the procedure Although the normal con

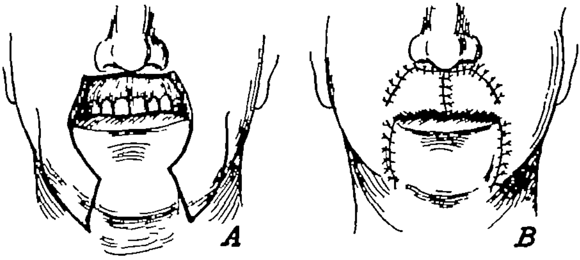


Fig 827

A. Shows two rectangular flaps removed from the area lateral to the lower lip and chin.
B. The flaps are raised, approximated, and sutured.

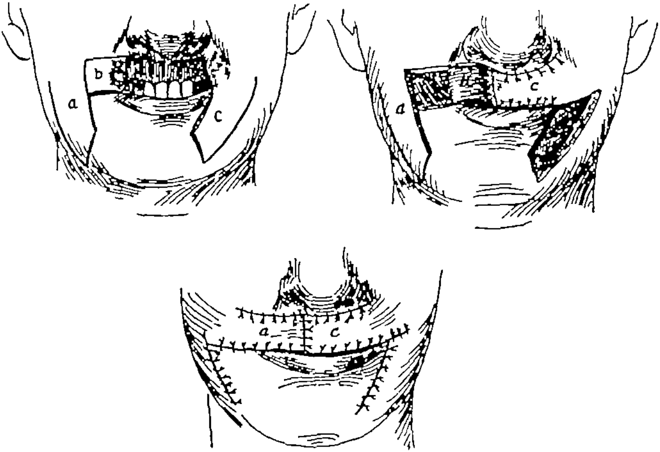


Fig 828. Reconstruction of entire upper lip with full thickness flap (C) taken from one side and skin flaps (A, B) from the other Skin flap (B) is inverted to form the inner lining of flap (A) The remaining defect is easily approximated.

tour of the mouth and lower portion of the face are disturbed by this type of procedure the restoration of the lip is the primary consideration and justifies the resulting secondary deformity

A full thickness rectangular Sedillot type flap is raised from one side of the lower lip in favorable cases and a reversed hinged skin flap on the other side (Fig 828) similar to that previously described in the Ferris

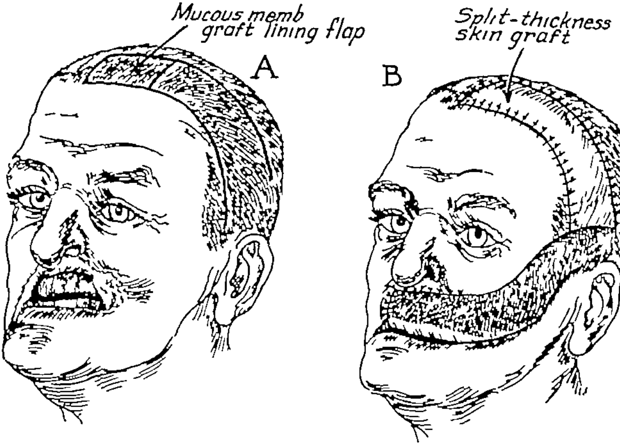


FIG. 829 Temporal forehead flap for the repair of a defect of the lip and cheek.
A. Outline of flap The upper portion of the flap comprises the scalp and is lined with a graft of mucosa from the oral cavity
B. The hair bearing scalp portion of the flap forms the outer covering and the mucosa lined portion the inner lining of the defect

Smith technique, (see Fig 828) The hinged flap forms the inner lining and an additional skin flap provides the covering the combined flaps provide sufficient tissue to form the upper lip (Fig 828) If a full thickness flap is taken from one side of the mouth flaps of skin only should be taken from the other side to avoid sectioning the cheek wall on both sides, and to preserve maximum muscular function

Distant Flaps

The use of a flap from a distance to reconstruct the entire upper lip must be considered only as a last resort in patients in whom the surrounding tissues are scarred or deficient and cannot be employed (Fig 829) *Distant flaps have merit in partial loss* of the lip as the remaining portions of the lip although with limited muscular activity transmit a degree of muscular control to the reconstructed portion Replacement of the entire upper lip by a distant flap which contains no muscle tissue, despite the flaccidity of the flap permits the patient to bring the lips together and to retain food and liquids in the oral cavity during mastication and deglutition In some cases it is possible to transfer nasolabial flaps from each side as shown in Figure 815 The flaps, containing orbicularis muscle fibers, are transposed into the lateral portion of the defect. The remaining portion of the upper lip is provided by a distant flap transferred preferably from the forehead as a temporal flap or from *the chest or abdomen A nasolabial flap on* one side of the defect is transferred and

sutured to the distant flap after the distant flap has healed and its pedicle is severed the nasolabial flap on the other side is prepared and sutured to the distant flap This technique supplies a degree of muscular function

Lengthening the Upper Lip

The term lengthening is commonly used to designate an increase in height of the upper lip Lengthening an upper lip which has been shortened as a result of tissue loss and scarring, may be achieved by a simplification of the technique attributed to Teale (1857) A diagonal incision is made through the full thickness of the lip (Fig 830) and the flaps are imbricated one above the other by sliding the cut surfaces until the desired increase in lip height is obtained (Fig 830) A similar procedure, in reverse, may be employed to decrease the height of the lip

DEFORMITIES OF THE LOWER LIP

Superficial Deformities

Operations outlined for the restoration of the upper lip can be applied to defects of the lower lip by the simple process of reversing the flaps One important factor however must be considered. A flap transposed to the upper lip is anchored to the base of the nose and is maintained in correct position by gravity a flap used to restore the lower lip particularly if its base is below the chin tends to retract downward as a result of gravity A liberal amount of tissue must therefore be mobilized and secondary supporting flaps may be required. The necessity for employing supporting flaps to counteract the tendency for downward retraction of the reconstructed lower lip was realized by Lallemand (1824) Blasius (1839) and Langenbeck (König 1898) who used various types of supporting flaps The method of providing supporting flaps which we employ is illustrated in Figure 831

Distortion of the Corner of the Mouth

Correction of an upward distortion of the corner of the mouth by transposing a tongue-shaped skin flap from below to the upper lip has been described previously (see Fig 804) A similar procedure, in reverse, may be applied if the corner of the mouth is retracted downward (Fig 832)

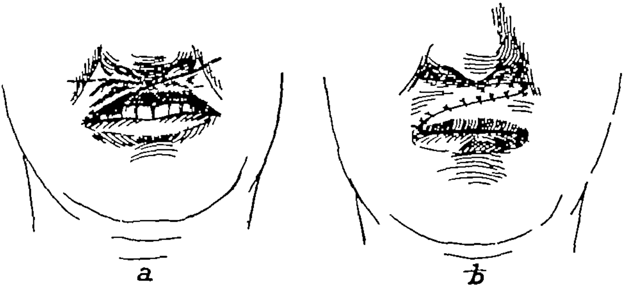


Fig 830. Lengthening the upper lip

A. Lines of diagonal incisions.

B Sliding the cut surfaces together and suturing them produce the desired result.

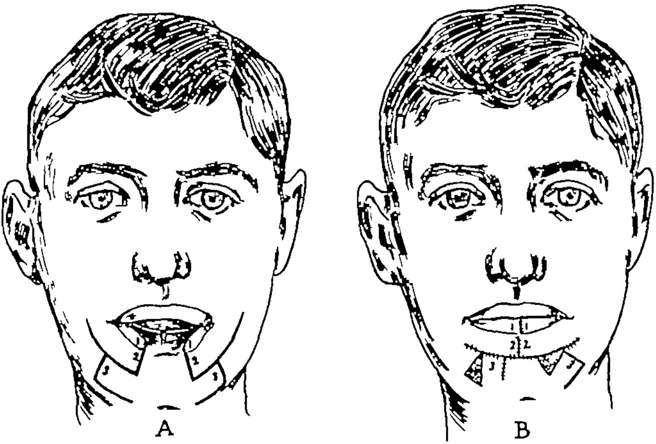


FIG 831 Supporting flaps used in reconstruction of the lower lip

A. Two supporting flaps are outlined (No. 3)

B The lower lip is repaired by flaps, (No. 1 2) and the supporting flaps (No. 3) prevent downward retraction of the reconstructed lip.

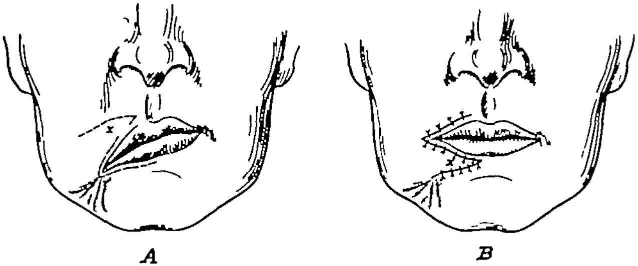


FIG 832. Distortion of the corner of the mouth

A. Diagram showing Z-flap incision for repair of the lower lip (Serre 1812)

B. The flap is brought down and sutured into the defect produced by the upward displacement of the corner of the mouth.

A B

Fig 833

A. Photograph showing distortion of the corner of the mouth due to loss of skin at the side of the lower lip.
B. Photograph after operative procedure illustrated in Figure 834

If the distortion is due to the pull of broad cicatricial areas which are usually associated with considerable loss of soft tissue, a skin flap from the vicinity of the upper lip may not be available. The lateral ends of the upper and lower lips may be brought together in their proper relationships after the scar tissue is excised the remaining raw area is covered by a flap from below (Figs. 833 834)

Ectropion of the Lower Lip

Scars resulting from burns are the most frequent cause of lower lip retraction the contracted skin everting the mucosa The retraction may be slight only a little more than the normal amount of mucosa being exposed, or the ectropion may be extensive, the lower lip being pulled down toward the chin The lip and chin tissues following extensive loss of skin are sometimes retracted downward due to vertical contracture of the skin of the neck.

In moderate contractures, an incision below the vermilion border permits the lip to assume a normal position the resulting defect is covered with a full thickness skin graft, or a flap from the nasolabial region (Fig 835) A preliminary delay procedure may be required to insure viability if the nasolabial flap is long and narrow Such

Fig 834 Diagram showing method of correction of distortion of the corner of the mouth. The defect resulting from the excision of scar tissue is repaired by a flap transposed from the side of the lower lip the tension of the lower lip is relieved by a horizontal incision across the lip.

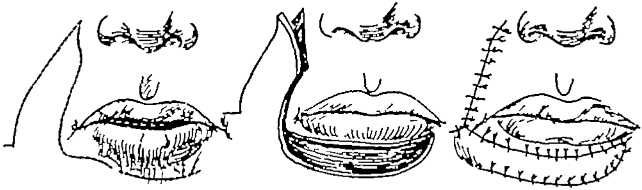


Fig 835. Correction of ectropion of lower lip by means of a nasolabial flap.

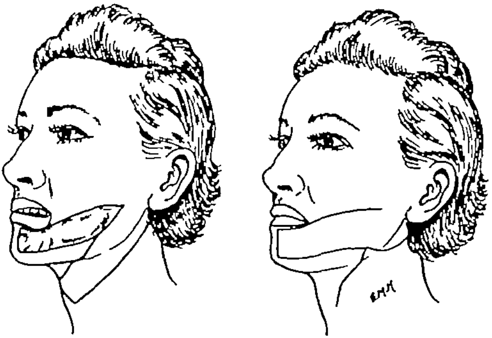


Fig 836. Diagrams showing utilization of a flap taken from the side of the neck.

flaps are preferred to skin grafts because there is less subsequent contraction than that which follows skin grafting A rectangular transposition flap from the submandibular portion of the neck may be employed in more extensive ectropion when most of the skin of the lip is scarred (Fig 836 837) A single flap may suffice to correct the deformity two flaps are used in extensive defects, one from each side of the neck The junction of the flaps should be along an oblique line to avoid a vertical line of junction a possible cause of postoperative downward retraction of the lip If the skin of the neck has not been injured and is well vascularized and healthy the donor area of the flap is easily closed by direct approximation

Bipedicled skin flaps from the neck have been used to cover the lower lip and chin (Figs. 838 839)

The success obtained by bipedicled flaps from the neck depends to a large extent upon adequate repair of the secondary defect produced by the mobilization of the neck flap Skin grafts placed in neck defects tend to contract postoperatively The contraction may result in downward displacement of the flap thus affecting the appearance during the immediate postoperative period The suprahyoid region is the most favorable area in the neck for

A B

Fig 837 Ectropion of lower lip corrected with flap from the neck.
A. Retraction of the lower lip and scar of the side of the face resulting from burn.
B. Result after operative procedure shown in Figure 836.

successful skin grafting because the graft is supported by the suprahyoid musculature. Bipedicled flaps of the neck should therefore be removed from this area whenever possible. Thick split thickness skin grafts are employed to repair the secondary defect in the neck for less postoperative contraction occurs when thick grafts are used. The lower lip, chin and side of the face are usually deformed by scar contractures in extensive burn deformities In male patients, the entire hairy section of the neck may be raised as a bipedicled flap to repair the entire lower part of the face in one operation (Fig 840) Bipedicled flaps from the neck to cover a limited area of the chin may result in considerable puckering at the ends necessitating removal of a triangular piece of tissue either at the same operation or later when a large defect of the neck may be covered by means of rectangular skin flaps from the chest the secondary defect on the chest is covered with a skin graft.

The use of pedicled flaps of skin from the chest to repair the neck defect is advantageous because of less contraction of such flaps than that which ensues when skin grafts are employed to restore a defect of the neck. Skin grafts to cover the secondary defects on the chest are placed over the chest wall a favorable recipient site.

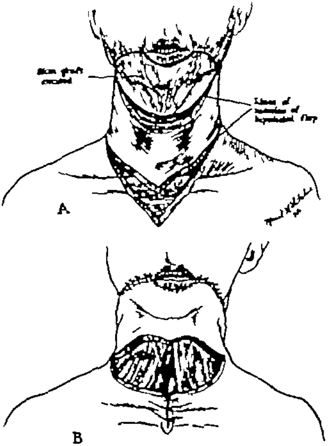
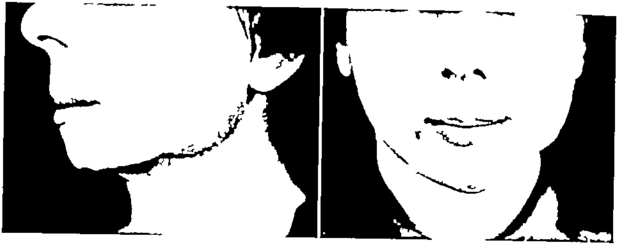


Fig. 838

A. After excision of blanched skin graft seen in Figure 839 a bipedicled neck flap was outlined.

B. The bipedicled neck flap was raised and sutured to cover the defect of the lip and chin. Because there was sufficient loose tissue of the neck it was possible to close the raw area at the lower part of the neck by approximation of the borders of the wound, thus obviating the need for a skin graft.



A B

Fig. 839

A. A conspicuous, blanched skin graft adherent to the mandible.
B. Result of operative procedure shown in Figure 838.

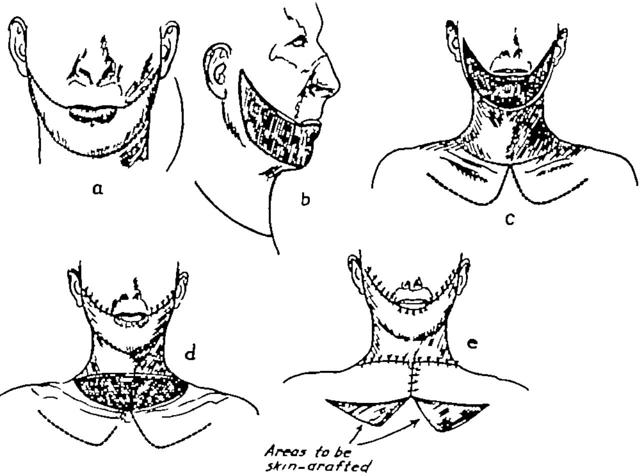


Fig. 840. Bipedicled neck flap for restoration of skin defect of the lower lip, chin and sides of the face.

A. Outline of incisions for resection of scar tissue.

B. Resulting defect.

C. Outline of incisions for the bipedicled neck flap and for secondary defect at the base of the neck, is an unfavorable site for free skin grafting because of the motion of the thyroid cartilage during respiration and deglutition.

D. Flaps from the chest transposed to cover the secondary defect at the base of the neck. Photographs of the patient are shown in Figure 1110, Chapter 29.

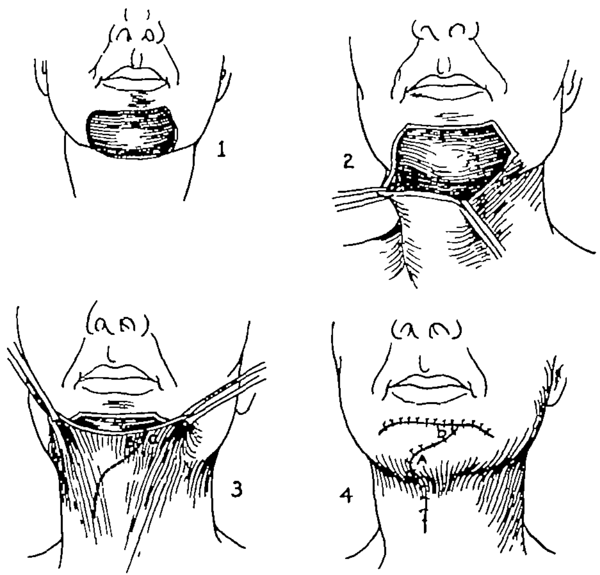


Fig. 841 Diagram showing various steps in the repair of a defect of the chin. The flap was split in the ter creating two triangular flaps which fitted accurately into position. In this case it was possible to take antage of the abundant loose skin of the neck.

In some cases particularly in older indi luals in whom an abundance of loose n is available, the defect is closed by aple advancement. The flap is incised igonnally through the mid portion to oid puckering of the ends (Figs. 841 and 2) Contracture of the skin of the neck ust be avoided to prevent downward trac on upon the lower lip and chin The pre ntion and treatment of contractures of e skin of the neck are discussed later in is chapter

Entropion of the Lower Lip

In entropion of the lower lip the skin d vermilion border of the lip are usually uninjured but the lip is retracted toward the buccal cavity Such deformities, due to laceration and loss of mucosa of the lip occur in mandibular fractures associated with loss of anterior teeth and alveolar processes The authors have seen cicatricial entropion of the lower lip in children who sustained burns of the mouth caused by con tact with live wire" electric sockets (Fig 843 see also page 1035)

Adherent scars of the mucosa in the buc cal sulcus are excised An incision is then made in the buccal sulcus posteriorly to the region of the second or third molar tooth the incision is extended vertically through the mucosa of the cheek for a distance of 2

Fig 842

A Photograph showing burn over the chin and lower part of the lower lip

B Result after completion of the procedure outlined in Fig 841

Fig 843

A Photograph of a child who suffered electric socket burn of the lip at the age of two years In addition to loss of the upper border of the lower lip there was a contracture of the mucosa, binding the lip to the alveolar process.

B Result following intraoral operation illustrated in Figure 814

or 3 cm (Fig 814) The two flaps of mucosa thus outlined and raised on each side of the mucosal defect of the lip are brought together and sutured by the V Y technique (Fig 811) The elasticity of the mucosa permits the closure of fairly large-sized defects. Missing teeth and alveolar bone should always be replaced by a suitable oral prosthesis to support the lip and to prevent subsequent contracture thus obtaining the full benefit of the operative repair In extensive scarring skin grafting by the epithelial inlay technique is indicated after the scars are excised (see Chapter 25)

Full Thickness Defects of the Lower Lip

Lacerations through the full thickness of the lip do not usually result in tissue loss. If

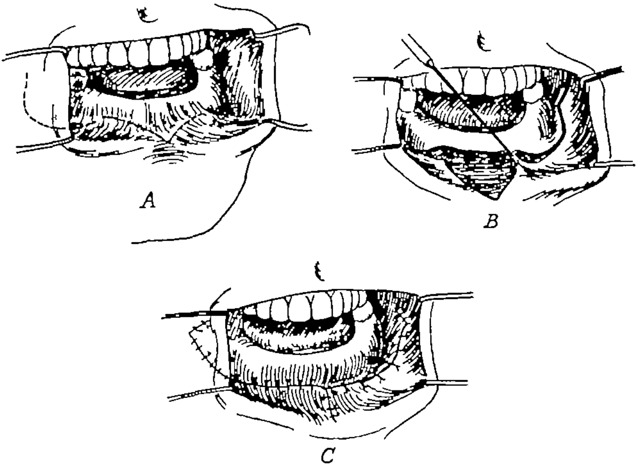


FIG 844

A. Outline of incisions in buccal sulcus for release of contracture causing entropion of the lower lip.

B. Mucosal flaps are raised

C. Suture of the mucosal flaps by the V–Y method thus releasing the contracture.

these are not repaired early and allowed to heal spontaneously considerable distortion of the lip occurs (Fig 845*A*) After scars and adhesions along the margins are excised, the tissues can usually be restored by direct approximation (Figs. 845*B* and 846) although a supporting flap is sometimes necessary to compensate for tissue loss due to scars or infection Figure 847 shows the technique employed for correcting such a defect of the lower lip the lip was raised into its normal position in this case, and a supporting vertical flap of skin was used to close the secondary defect (Fig 847*C*)

Deformity from full thickness loss of the lower lip may be due to loss of median or lateral sections, or loss of the entire lip

Median Defects of the Lower Lip

Modifications of the operative technique outlined for the restoration of the median section of the upper lip may also be applied to the lower lip

For small defects, the edges of the wound are excised and the V shaped defect is closed by direct approximation care being taken to avoid a straight line of suture by employing the z plasty technique (Fig 848) In larger defects tightening of the lip occurs and additional subsequent surgery is required to release tension

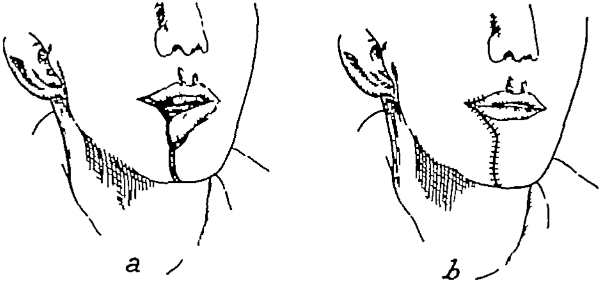
Median retraction of the lower lip often occurring in traumatic cases may be corrected by a rectangular or curved flap on each side of the lip, joined medially in a vertical position (Fig 849) The incisions outlining the flaps need not extend below the labiomental fold nor the horizontal incision beyond the level of the corner of the mouth (Figs. 849 and 850)

In larger median defects, the flaps are also larger these are shaped as rotation flaps

A B

FIG 845

A. Preoperative photograph showing scar contracture of the lower lip.
B. Result achieved after technique illustrated in Figure 846.



a b

FIG 846 Restoration of the lower lip following the removal of adherent scars
A Lines of excision of scars.
B The lower lip is released from its bony adhesions and replaced.

and extend toward the lower border of the mandible and upward laterally to the corners of the mouth (Figs. 851 and 852) A variety of such flaps, designated as fan flaps by Gillies (1957) are illustrated in Figure 853 This technique is best indicated when the upper lip cannot be utilized.

To supply sufficient mucosal lining incisions are made along the buccal sulcus posteriorly to the second or third molar tooth

on each side these incisions are then extended vertically through the mucosa of the cheek for a distance of 2 or 3 cm (see Fig 844) If the median defect is too large, the available mucosa is inadequate to supply the inner lining, even though a sufficient amount of skin may be secured by raising large flaps from each side of the face. In such cases, provisions must be made to cover the inner side with a lining provided by a split thickness skin graft, or the appearance as well as function of the lower part of the face may be affected. The epithelial inlay technique is employed in such cases (see Chapter 25)

Estlander Operation (1877)

Estlander described an operation for the repair of lateral defects of the lower lip utilizing a flap taken from the lateral portion of the upper lip which includes the corner of the mouth (Fig 854) The flap is turned down on a narrow pedicle supplied by the labial artery

Two modifications of Estlander's operation may be employed for the reconstruction of median defects of the lower lip The first modification is to transpose a flap based upon the lateral portion of the upper lip and the corner of the mouth (Fig 855) The second modification of the Estlander procedure may be employed in smaller defects A median pedicle is employed in defects located slightly to one side of the mid line The flap which includes only a portion of the upper lip and does not involve the corner of the mouth avoids distortion the secondary defect of the upper lip is closed by direct approximation (Fig 856) Thus procedure is a reverse Abbé-type operation

The typical Estlander operation (Fig 855) results in a rounded corner of the mouth which requires a secondary procedure similar to that described in Figure 874 to reestablish the normal contour of the angle of the mouth.

The vascularization of the flap must be preserved in all these operations by respecting the continuity of the labial vessels included in the narrow pedicle. The vessels lie closer to the oral mucosa than to the skin this anatomical fact should be borne

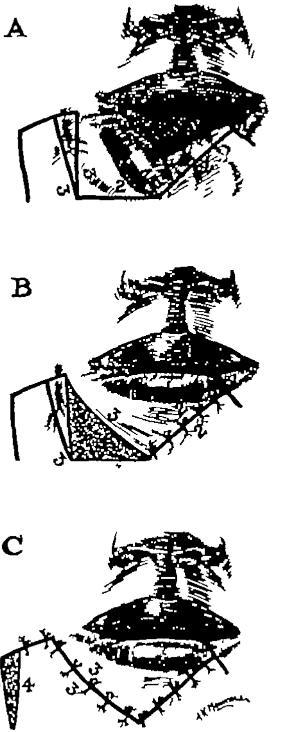


FIG 847 Diagram showing defect of the lower lip. A lateral flap, large enough to supply a good outline to the lip, is raised. A vertical flap from the cheek is used to cover the raw area below the lip flap

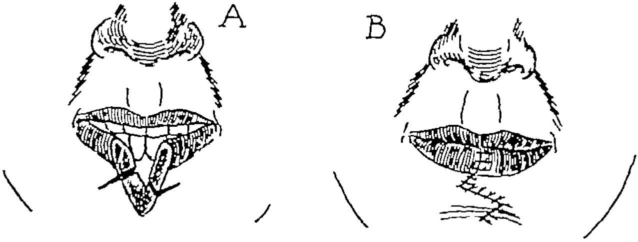


FIG. 818. Z-flaps to avoid linear contracture of lip wound
A. Z-flaps are outlined prior to suture.
B. Appearance of the lip after suture and transposition of Z-flaps.

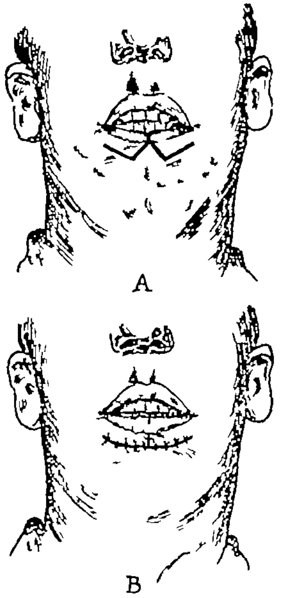


FIG 819 Diagrammatic drawing of incision lines utilized in the repair of a median retraction of the lower lip

in mind when the incisions for outlining the flap are made.

A portion of the upper lip is used to supply additional tissue to the lower lip by employing a modification of the Estlander operation The median gap (Fig 855) is closed by shifting the lateral portion of the lip to the mid line this procedure transfers the defect from the median to the lateral portion of the lip (Fig 855*B*) The resulting V shaped space is closed by a triangular Estlander flap from the lateral portion of the upper lip (Fig 855*C* *D*) This operation is preferable to the transfer of the medial section of the upper lip a procedure which usually destroys the contour of the philtrum Median defects of the lower lip are also successfully repaired by Kazanjian's modification of the Stein operation

The Modified Stein Operation

Stein (1818) described an operation consisting of transferring two full thickness triangular shaped flaps from the philtrum portion of the upper lip to repair a defect of the lower lip (Fig 857 Fogh Andersen 1918) Each flap remains attached to a small laterally situated pedicle which contains the labial vessels This operation is satisfactory in principle but the resulting loss of the normal contour of the philtrum of the upper lip is a serious inconvenience A modification of the procedure (Kazanjian and

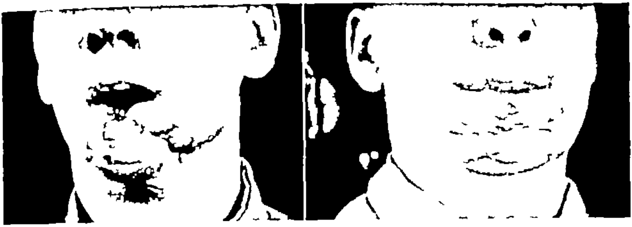


FIG 850

A. Photograph before surgical procedures diagrammatically outlined in Figure 851

B. Early result four weeks after operation.

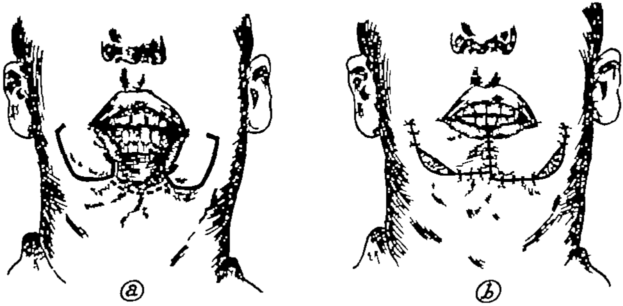


FIG 851 Median defect of the lower lip

A. Outline of incisions for rotation flaps.

B. Flaps rotated medially to repair the lip

Roopenian, 1954) preserves the integrity of the philtrum the triangular flaps are removed from each side of the philtrum thus leaving the structure intact (Fig 858)

The Bernard Operation

The operation of Camille Bernard (1853) utilizes the principle of lateral advancement flaps facilitated by the excision of Bürow's triangles a modification of Bernard's operation is shown in Figure 859 The oral mucosa is preserved when the Bürow triangles are excised the mucosal triangular flap with the base of its pedicle below is employed to restore the vermilion border of the lateral portion of the reconstructed lower lip

Lateral Defects of the Lower Lip

Moderately sized defects of the lateral part of the lower lip may be repaired by a nasolabial flap or by the Estlander operation

Nasolabial Flap

Von Brüns described the use of nasolabial flaps comprising the full thickness of the cheek for the reconstruction of the lower lip The incisions outlining the full thickness nasolabial flap are made in the nasolabial

Fig 832

A. Reconstruction of the lower lip presenting a median defect

B. Result obtained by two rotation flaps as shown in Figure 851

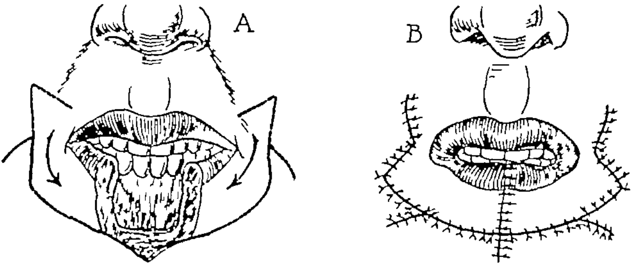


Fig 833 Reconstruction of median defect of the lower lip

A Outline of incisions for Gillies fan flaps

B Position of the flaps after transfer

fold upward and outward around the base of the ala and downward in the cheek to a point lateral to the corner of the mouth The flap is raised and the secondary cheek defect is approximated without difficulty because the suture line corresponds to the nasolabial fold it is quite inconspicuous. The full thickness flap is sutured to the remaining

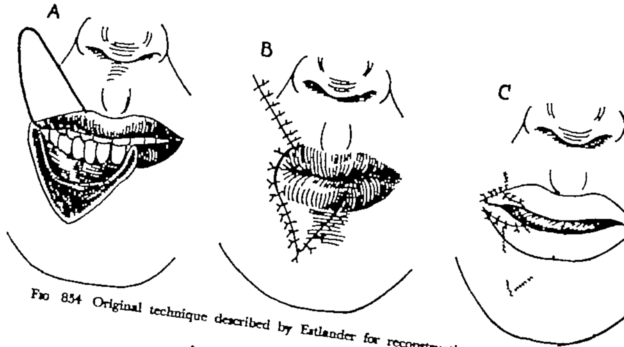


Fig 854 Original technique described by Estlander for reconstruction of lower lip defect

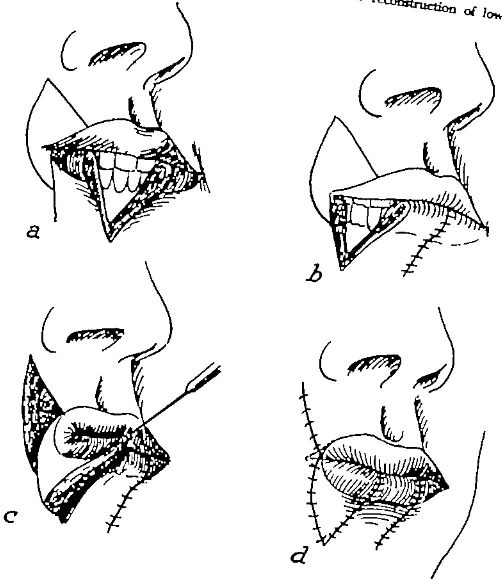


Fig 855 Modified Estlander operation for the repair of a large median defect of the lower lip including the corner of the mouth.

A. Median defect and outline of incisions.

B. Median defect is closed by shifting the remaining lateral lip tissue into the defect.

C. The Estlander flap which includes the corner of the mouth is rotated downward into the secondary de-ect in the lateral portion of the lower lip.

D Appearance at the conclusion of the operation. A secondary procedure illustrated in Figure 874 is n-y to restore the angle of the mouth.

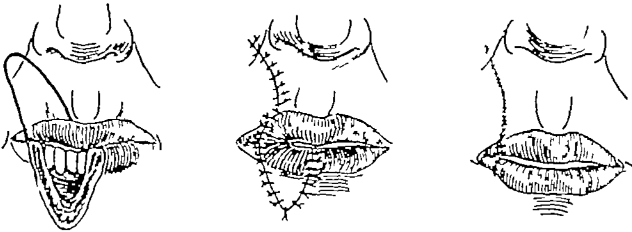


FIG. 856. Modified Estlander operation. The base of the flap does not include the angle of the mouth, thus avoiding distortion of this structure

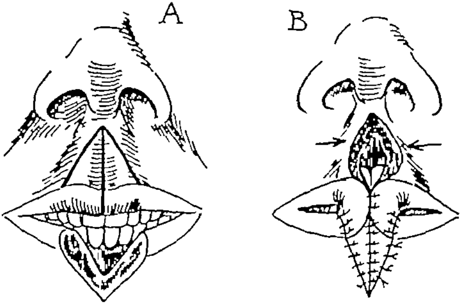


FIG. 857 Technique described by Stein for reconstruction of the lower lip
A. Outline of flaps taken from the center of the upper lip.
B Transfer of flaps for the repair of a median defect of the lower lip

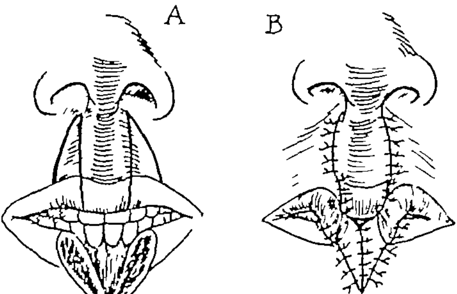


FIG. 858. Kazanjian modification of the Stein operation
A. The flaps are taken from the upper lip lateral to the philtrum in order to avoid distortion of this structure.
B Position of flaps after completion of operation.

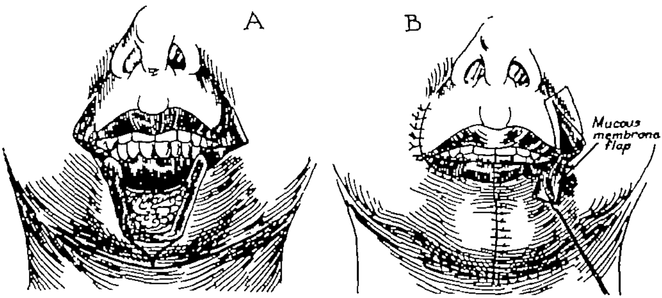


Fig 859 Camille Bernard operation (modified)

A. Bürow triangles removed from the lateral portions of the upper lip above the corner of the mouth.

B. Position of flaps after closure of the median defect of the lower lip Note the use of the mucous membrane flap from the excised Bürow triangle to provide the vermilion border of the lateral portion of the reconstructed lip.

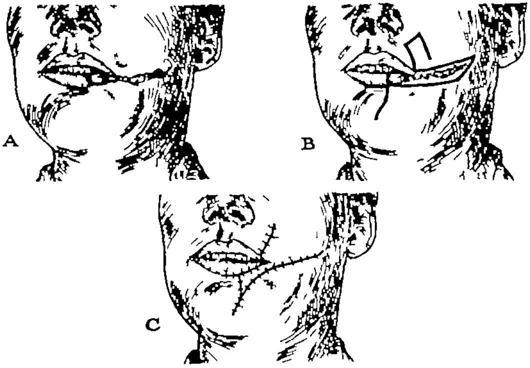
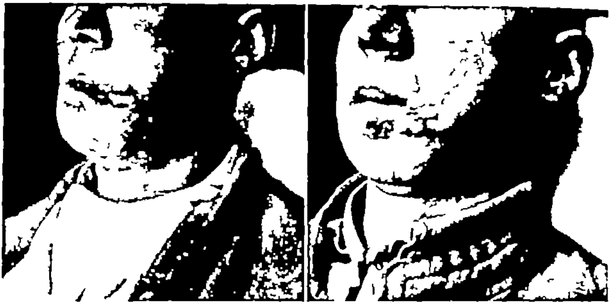


Fig 860

A and B. Small full thickness defect of the lip and skin of the cheek repaired with full thickness nasolabial flap. This type of flap was used because of the deep scar on the cheek which would interfere with the blood supply of the typical nasolabial flap.

C. Diagram showing flap sutured



A B

FIG 861

A. Photograph showing small full thickness defect of the lip and skin of the cheek.
B. Result after treatment illustrated in Figure 860.

A B

FIG 862

A. Outline of full thickness cheek flaps to be used for reconstruction of lower lip.
B. Lip reconstructed by transfer of the flaps.

section of the lower lip (Figs. 860 and 861). The same principle is applied to larger defects (Fig 862)

The Estlander Operation (1877)

The Estlander operation previously described is a classical procedure for the restoration of a defect involving the lateral portion of the lower lip. The typical Estlander operation (see Fig 851) employed in large defects of the lateral portion of the lower lip results in an artificial roundness of the angles of the mouth which must be corrected in a later stage by the operation illustrated in Figure 874 In smaller defects involving the lateral portion of the lower lip a modi

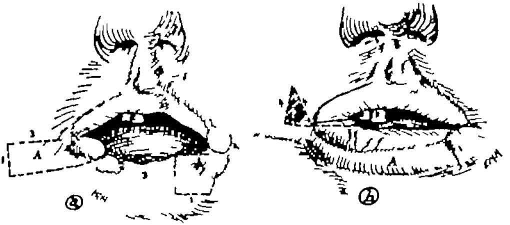


FIG 863 Outline of lateral rotation flaps for reconstruction of lower lip Flap (A) is rotated 180 degree and the opposite flap is rotated 90 degrees. Each flap contains muscle tissue, a good blood supply from the labial artery and sufficient skin and mucosa for the new lip. The tongue shaped flap (2) contains skin and mucosa and is used to reconstruct the angle of the mouth.

A B

FIG 864

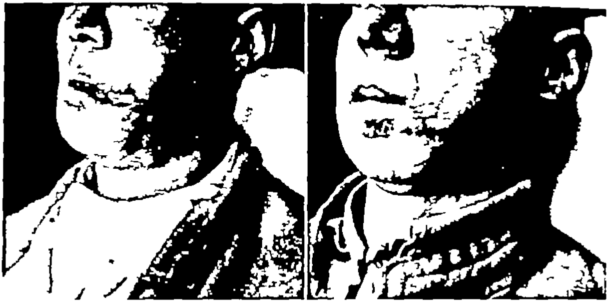
A. Loss of the greater part of the lower lip.

B. Condition five months after the repair by the technique shown in Figure 863

fied Estlander procedure a reverse Abbé operation employs a flap taken from the upper lip which does not involve the corner of the mouth and which is vascularized through a median pedicle (see Fig 856) A triangular flap from the lateral aspect of the upper lip is rotated on a narrow pedicle containing the labial artery into the defect of the lower lip (see Fig 856) A modification of the Estlander operation utilizes a flap with the corner of the mouth as its base (see Fig 855)

Lateral Rotation Flap

A flap similar to the one described previously for the reconstruction of the lateral portion of the upper lip is particularly useful (Figs. 863 and 864) when the greater part of the lower lip has been destroyed. The remaining lip tissue is freed and rotated to a horizontal position and a measured rectangular horizontal flap is taken from the opposite cheek. Because the base of the flap extends into the cheek, a sufficient amount of



A B

Fig 861

A. Photograph showing small full thickness defect of the lip and skin of the cheek.
B. Result after treatment illustrated in Figure 860.

A B

Fig 862

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B. Lip reconstructed by transfer of the flaps.

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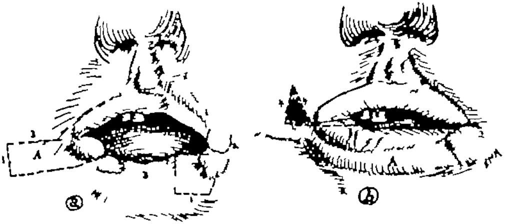

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A B

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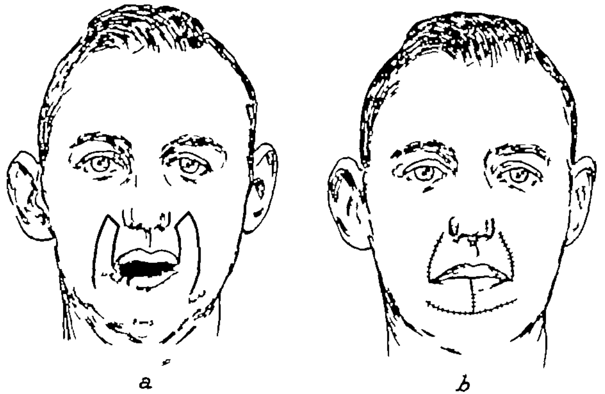

FIG 865 Diagrams showing bilateral full thickness nasolabial flaps for complete loss of the lower lip. The procedure results in tenseness of the upper lip

A. Lines of incisions for nasolabial flaps.

B Flaps brought together and sutured

skin and mucosa can usually be obtained if the skin loss does not extend below the junction line of the lip and chin

Complete Loss of the Lower Lip

In extensive or total loss of the lower lip we have successfully employed two techniques for reconstruction The first technique consists of shifting a rectangular full thickness von Brüns type nasolabial flap from each side of the upper lip (Figs. 865 and 866) This procedure, although providing an adequate amount of tissue tends to tense the upper lip and affects its mobility because muscle and nerve fibers of both sides are severed Pierce and O Connor (1951) have advocated a variation of this technique in which flaps of skin only are employed rather than full thickness flaps. One flap provides the lining and the other the covering of the new lip. The lining flap should be raised from the area of non hair-bearing cheek skin lateral to the nasolabial fold to avoid the introduction of hair-bearing skin into the oral cavity

In the second technique, a flap comprising the full thickness of the cheek wall is elevated from the nasolabial area on one side and a full thickness horizontal cheek flap is raised on the opposite side (see Fig 867) The function of the orbicularis oris fibers of the upper lip and of the quadratus labii superioris muscle are thus preserved on one side

Modified Dieffenbach Operation

In addition to the two techniques described above reconstruction of the lower lip may also be achieved by means of a third technique in which large rectangular-shaped full thickness cheek flaps are transposed from each side of the face after the technique of Dieffenbach (1831) modified by Adelmann (Szymanowski 1858) Nélaton and Ombrédanne (1907) and May (1911)

An incision is made through the skin and

A B

Fig 866

A. Loss of the lower lip
B Result following reconstruction by technique shown in Figure 865

the superficial muscles of expression extending from the angle of the mouth to a point in front of the tragus of the ear (Fig 868*A*) the incision extends to but not through the oral mucosa When the incision reaches the anterior border of the masseter muscle it extends to but not through the parotid masseteric fascia. The external maxillary artery and anterior facial vein are identified in the course of the incision and are sectioned and ligated Stensen s duct is located immediately above the line of incision, which should extend below the level of Stensen s duct to avoid injury to the duct. Localization of the duct is facilitated by injecting methylene blue through the oral opening of the duct on each side, after catheterization with a fine-calibered cannula A second incision is then extended downward from the posterior end of the first incision, in front of the tragus to a point situated below the angle of the mandible. The flap thus outlined, which includes the facial artery and vein is raised from the parotid masseteric fascia.

The oral mucosa, dissected from the structures situated above the horizontal line of incision for a distance of approximately 1 cm is incised at this level This procedure provides an excess of oral mucosa which is used to provide a vermilion border for the reconstructed lip (Fig 868*B*)

A vertical incision is now made through the oral mucosa at a point posterior to the anterior border of the masseter The lower end of this incision reaches the buccal sulcus and it is extended forward through the mucoperiosteum of the mandible. The mucoperiosteum is incised at a level immediately below the gingival margin in order to preserve as much of the mucoperiosteum as possible to supply a lining for the cheek flap Although the oral vestibule is obliterated by this procedure, it is restored at a later date by the epithelial inlay procedure.

Subperiosteal elevation is then extended downward to the level of the lower border of the mandible particular care is exercised in elevating the periosteum immediately anterior to the border of the masseter to avoid injury to the external maxillary vessels which nourish the flap The flap is completely freed from the parotid masseteric fascia in its posterior portions the submaxillary gland is visualized in this area.

A similar procedure is employed to prepare the flap on the opposite side of the face

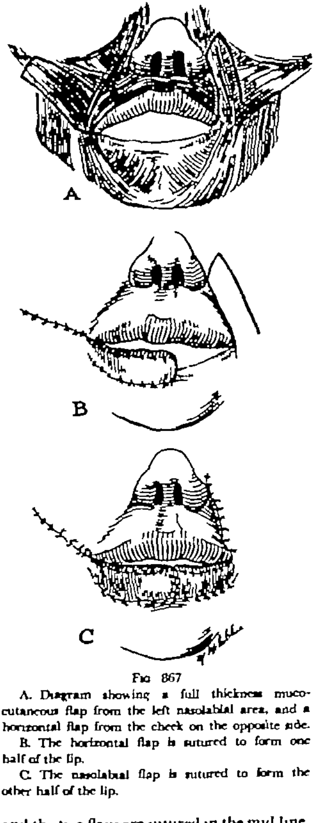

Fig 867

A. Diagram showing a full thickness mucocutaneous flap from the left nasolabial area, and a horizontal flap from the cheek on the opposite side.

B. The horizontal flap is sutured to form one half of the lip.

C. The nasolabial flap is sutured to form the other half of the lip.

and the two flaps are sutured in the mid line, thus restoring the lower lip (Fig 868C) The secondary triangular skin defect over the masseter muscle is closed by the V Y method.

A weak area due to the raw area which results from deficiency of the oral mucosal lining remains immediately anterior to the masseter muscle. May (1941) has suggested filling this weak area with a flap of muscle from the anterior portion of the masseter

The Dieffenbach operation is only occasionally applicable to defects of the lower lip resulting from injury (Fig 869) The procedure affords best results in aged patients subjected to extensive resection of the lower lip for the exenteration of malignancy and who frequently have metastatic involvement of the cervical lymph nodes requiring concomitant neck dissection The looseness of the facial tissues in older patients facilitates the procedure the age of the patient and the reserved prognosis in such cases justifies this type of procedure rather than the more complicated and lengthy reconstructive procedures required to rebuild a lower lip by means of flaps from a distance. Despite the poor function of the lower lip reconstructed by the Dieffenbach operation results are often more satisfactory than those obtained by the employment of distant flaps (Fig 870)

Defects of the Lower Lip and Chin with Loss of a Section of the Mandible

In extensive soft tissue loss of the lower lip and chin associated with loss of mandibular bone due to severe injuries such as gunshot wounds, we prefer large rotation skin flaps, employing an additional flap of neighboring tissue or tissue from a distance to provide the lining Treatment of such defects is intimately associated with restoration of the continuity of the mandible by bone transplantation (see Chapter 21)

Additional Reconstructive Procedures

Reconstruction of the Corner of the Mouth

Electrical and thermal burns cause severe deformities of the corner of the mouth. The principal types of deformity include (1) those limited to the corner of the mouth, and (2) deformities complicated by loss of a section of the lower lip. When the lateral

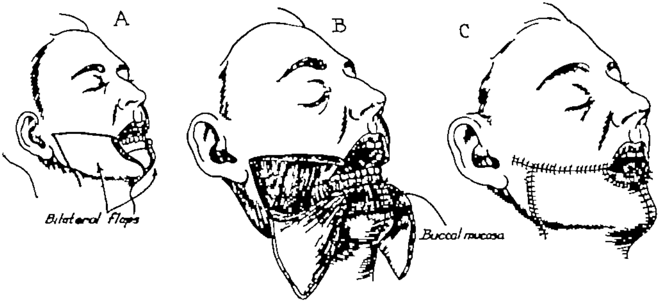

FIG 868. Dieffenbach operation (modified)

A. Outline of incisions through the full thickness of the cheek wall.

B. Position of flaps after suture in the mid-line.

C. The operation is completed.

(After Nélaton and Ombrédanne, 1907)

FIG 869 Dieffenbach-type operation for the repair of a defect of the lower lip. Two lateral flaps are outlined and extended from the corner of the mouth back to the anterior border of the masseter muscle below the level of Stensen's duct. The median scar is excised the lateral flaps are transposed medially and sutured.

FIG 870. Photograph showing repair of defect of the median part of the lower lip by vertical flaps from the sides of the defect as shown in Figure 869

portions of both upper and lower lips are involved the upper and lower lips become adherent for a varying distance from the corner of the mouth (Fig 871*A*)

Reconstruction of the corner of the mouth is not a simple procedure, and is more difficult when dense scar tissue is present. Two

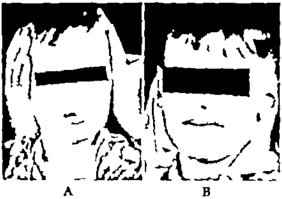

FIG 871

A. Photograph of child showing adhesions between the lips following electric socket burn.

B. Result obtained after operation illustrated in Figure 872.

(Figs. 871 to 873 from V H. Kazanjian and A. Roopenian Am. J Surg 88 884 1954)

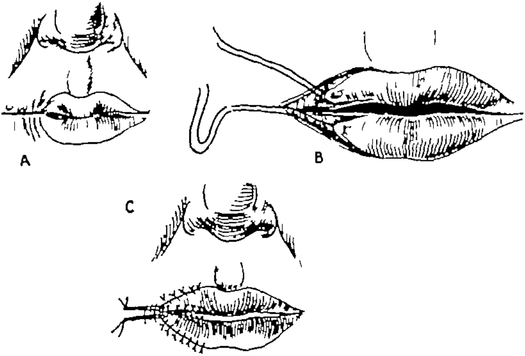

FIG 872

A Incision through the area of the adhesion.

B. Mattress sutures placed through the flaps of the vermilion border

C. The flaps of vermilion border have been advanced over the deficient area

procedures have given satisfactory results (Kazanjian 1954) the choice between the two depends upon the amount of mucosa remaining at the vermilion border

FIRST METHOD The adherent portions of the upper and lower lips are separated and the avascular scars are excised enabling the surrounding tissues to regain their normal elasticity the amount of surrounding tissue available for the repair then becomes apparent (Fig 872*A B*) The skin loss is negligible in most cases and mucous membrane alone is required to re-establish the normal outline of the mouth. If the raw areas at the corners of the upper and lower lips are not more than 1 to 1.5 cm in length an advancing flap from the vermilion border of the adjacent portion of the lip can be used to restore this area adequately (Fig 872*B C*). A horizontal incision is extended medially from the wound through the full thickness of the lip at the mucocutaneous line The incision should be of sufficient length to allow the flap of vermilion border mucosa to stretch to the new corner of the mouth where it is anchored by a mattress suture which extends from the tip of the flap through the subcutaneous tissues of the cheek and is brought out through the skin of the cheek at a distance from the new corner of the mouth (Fig 872C)

SECOND METHOD More extensive loss of the

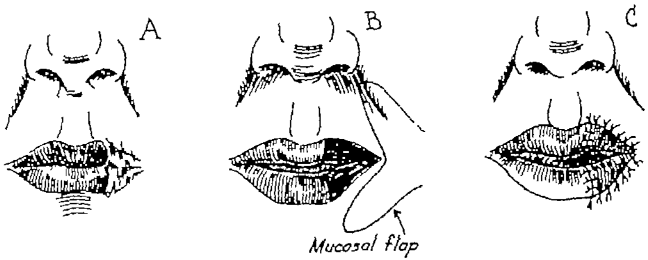

FIG 873

A. Scarred area joining the lips.

B. The scarred area has been incised design of the mucosal flaps.

C. Result obtained after transposition of the mucosal flaps.

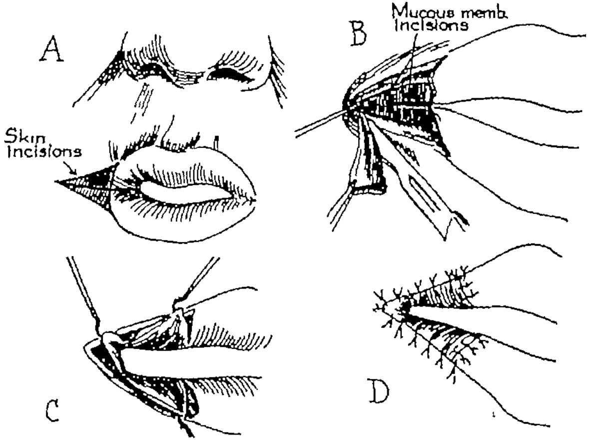

FIG 874 Technique of elongation of the oral fissure and restoration of the angle of the mouth

A. Outline of skin incisions.

B. Excision of skin and subcutaneous tissue exposing the oral mucosa. Outline of incisions through the mucosa.

C After incision three mucosal flaps are available.

D The mucosal flaps are sutured to the skin edges. Note the mucosal flap at the angle of the mouth.

vermilion portion of the lips cannot be re paired by the first technique. In such cases we have replaced the missing vermilion por tion of the lips by the transfer of mucous membrane flaps from the [illegible] (Fig 873). The wounds resulting from removal of these flaps are easily closed by approximation. The new corner of mouth

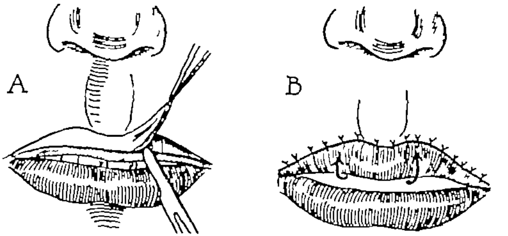

Fig 875 Advancement of the mucosa of the lip to restore the vermilion border
A. Excision of an outlined ellipse of skin.
B. Restoration of the vermilion border by advancement of a mucosal flap previously freed by underminin from the orbicularis oris muscle.

maintained by a mattress suture brought out through the cheek as in the first method the shifted mucosal flaps are anchored by the suture into the angle (Fig 873C)

Elongation of the Oral Fissure

This procedure is required after scarring of the angle of the mouth due to wounds or burns and occasionally following operations in which rotated flaps are employed to reconstruct the lips (Fig 874A) After determining the required length of the oral fissure a *horizontal incision* which avoids the oral mucosa is made through the skin and subcutaneous tissue (Fig 874A) An oblique incision is made through the skin only on each side of the previous incision (Fig 874A) and the two small triangles of skin thus outlined are excised (Fig 874B) A horizontal incision is then made through the mucosa to a point about 1 cm from the extremity of the skin incision (Fig 874B) The lateral end of the horizontal mucosal incision is joined at right angles by a curved incision through the mucosa this incision outlines an oval-shaped flap of mucosa which serves to line the new angle of the mouth an important technical detail which prevents subsequent contraction and shortening of the oral fissure during the healing period (Fig 874C) The edges of the mucosal flap are sutured to the edges of the skin : the corner of the mouth and the operatio is completed by suturing the mucosa to th skin of the upper and lower lips (Fig 874D)

Restoration of the Vermilion Border of the Lip

Restoration of the vermilion border i required after destruction by injury or t provide a new vermilion border in recor structed lips.

When the adjacent lining mucosa of th *lip is free of scar tissue it is freed from th* underlying muscular layer and advanced over the lip margin (Fig 875) Excision of a suitable amount of skin along the margin of the lip is a requirement previous to this procedure (Fig 875) Additional mucosa can be obtained from the opposing lip and transferred as a unipedicled or bipedicled flap when the adjacent mucosa is scarred (Fig 876)

A small Abbé-type flap is transferred from the opposing lip when shortness of tissue in the vermilion border is accompanied by tightness of the lip due to loss of tissue (Fig 877)

Suspension and Muscular Function of the Reconstructed Lower Lip

In reconstructing the lower lip attempts should be made to provide muscular flaps

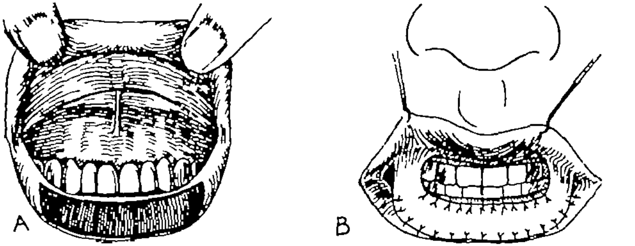

Fig 876 Restoration of the vermilion border with a bipedicled mucosal flap from the undersurface of the upper lip

A. Design of the bipedicled mucosal flap.
B. Bipedicled mucosal flap transferred from the upper lip to the lower lip.

Fig 877 Restoration of vermilion border by means of Abbé flap

A. Defect of the upper lip resulting from dog bite.
B. Abbé flap transferred from the lower lip.
C. Result obtained by Abbé procedure.

at the lateral portions of the reconstructed lip in order that the new lip contain some degree of muscular activity and also to counteract the tendency for downward retraction of the reconstructed lip through gravity

The use of full thickness flaps from the nasolabial area to form the lateral portions of the reconstructed lip is a practical method (see Fig 867) Another method is to suspend the lip by means of fascia lata passed through the thickness of the lip and anchored on each side in the cheek above the lateral to the nasolabial fold. Attempts to transpose a bipedicled flap of orbicularis oris muscle from the upper lip have not proved successful.

DEFORMITIES OF THE CHEEKS

Soft Tissue Deformities of the Cheeks

Deformities of the soft tissues of the cheeks resulting from trauma vary in extent from hypertrophic scars to full thickness defects of the cheek.

Readjustment or restoration of the skin over the parotid masseteric region is generally less difficult than in the cheeks and lips, for the parotid masseteric area is less mobile and therefore more suitable for skin grafting and skin from the adjacent temporal postaural and neck regions is available for transposed or rotation flaps. A hypertrophic scar of moderate size may usually

be eradicated by repeated partial excision undermining the surrounding skin and approximating the edges the greater part and often the entire scarred area may be removed in this manner Scars extending over a wide area cannot be repaired by simple approximation of the wound after excision of the scar tissue. In such cases, the defect must be repaired either by pedicled flaps or by skin grafting

Defects over the zygomatic area can be covered by a vertical transposed flap from the preauricular region The secondary defect remaining after transfer of the flap is closed by direct approximation after undermining the wound edges. If the secondary defect cannot be repaired by direct approximation a postauricular flap or free graft may be used examples of such flaps are shown in Figures 878 to 882.

A round or oblong area of scar tissue over the center of the cheek is repaired effectively

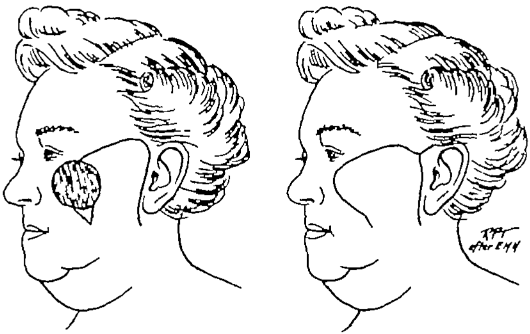

FIG. 878. A rotation flap from the preauricular region to cover a large defect of the zygomatic and infraorbital regions. The resulting defect is closed by approximation of the wound edges. This procedure is particularly useful in elderly people who have an abundant amount of loose skin.

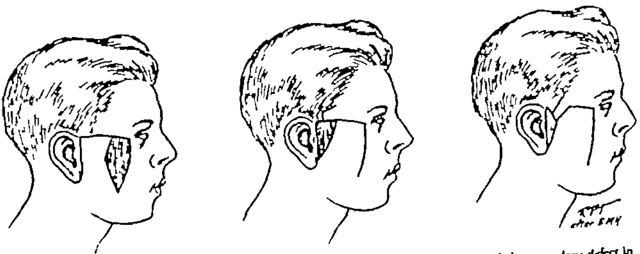

FIG 879 A vertical transposed flap is used to cover a defect over the zygoma, and the secondary defect in front of the ear is covered with a skin graft.

Fig 880. Photographs showing a defect of the zygomatic region (A) repaired by a transposed flap from the preauricular region (B) as illustrated in Figure 881

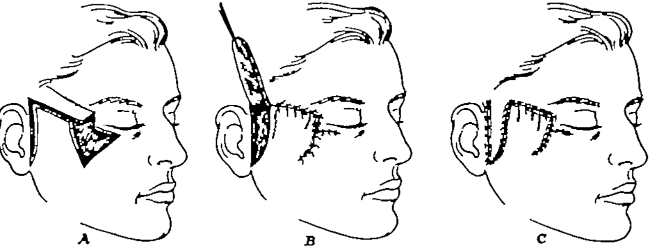

Fig 881

A. Diagram of defect pictured in Figure 880 The lines of incision for the flaps are shown.

B. The flap is advanced and sutured to cover the defect.

C. A horizontal flap from the temporal region is brought down and sutured to cover the preauricular defect.

by a flap extending from the pre and post auricular regions or from below the lower border of the mandible If the defect is too large to be repaired by a single flap an additional flap is obtained from the zygomatic or postaural regions such flaps have proved satisfactory and are illustrated in Figures 883 and 884

The primary objective in the repair of defects of the face is the shifting of a flap

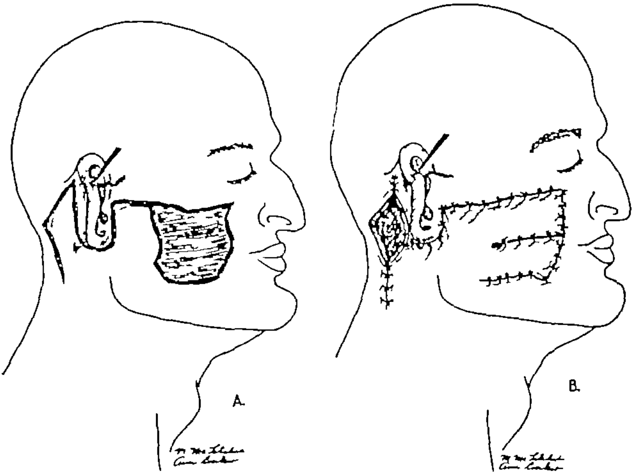

FIG 882

A. A defect of the center of the cheek and the outline of preauricular and postauricular flaps used in repair

B. U-shaped flap from the preauricular and postauricular region, shifted to cover the defect of the center of the cheek.

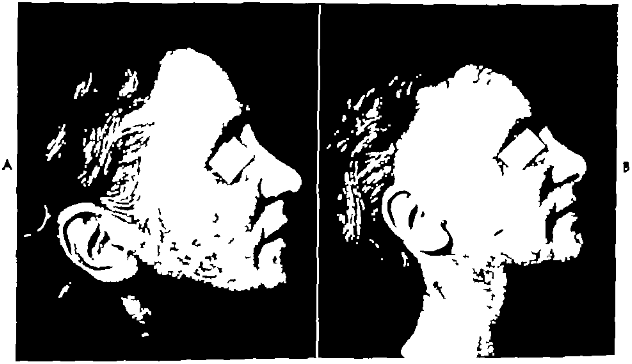

FIG 883 Photographs showing a large oval burn scar of the cheek

A. The scar was excised and a large skin flap from the pre and postauricular regions was advanced to cover the lower part of the defect.

B An additional rotating flap from the temporal region was brought down to cover the secondary defect The technique is illustrated in Figure 881

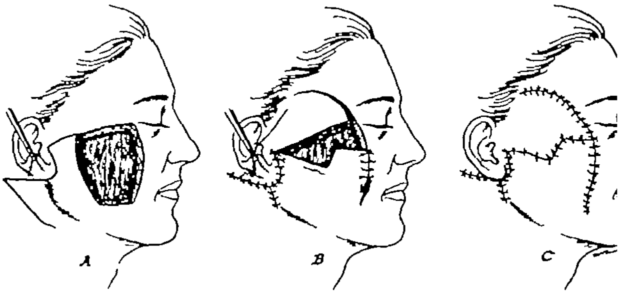

Fig 884 Diagrams illustrating the method or repair employed in Figure 883
A. Extent of defect and outline of pre and postauricular flap.
B. Flap brought forward to close lower half of defect.
C. Flap from temporal region brought down to close upper part of the defect.

of tissue from a neighboring region to cover the affected area the secondary raw area occasioned by the shifting of the flap is an important consideration The condition elasticity color and abundance of skin of the donor area of the flap also merit careful consideration previous to operation.

The scar may extend to the vicinity of the lateral nasal region in some surface deformities of the skin of the cheek. Such a condition may be adequately restored by the technique shown in Figure 885 An anterior vertical incision is extended from the edges of the wound along the nasolabial fold downward to the neck, and then horizontally backward the general outline of the flap is rectangular The neck wound is closed by direct approximation of the borders of the wound. An additional flap is mobilized for this purpose when indicated.

In considering defects which encroach upon the region of the neck, the problem of restoration becomes relatively simplified because of the looseness and abundance of skin available for donor flaps. For these reasons defects of the lower part of the face, involving the area in front of or below the lobe of the ear and over the angle of the mandible, are favorably located for repair

Defects over the angle of the man are repaired successfully by a flap taken behind the ear larger flaps when indi may be obtained from the same region 886) A scar line located in an area is not readily seen is obviously advanta (Fig 887)

The judicious employment of neck is an important consideration in the of defects of the lower portion of the The design of the flaps varies with th tent and location of the defect, but em must be placed on the principle inv which is the use of a maximum amo neck skin as a source of supply for ative procedures.

A large lesion over the angle of th and in front of the ear for example be repaired by vertical advancement flap from the neck. After excising the tricial area two parallel vertical inc are made from the edge of the defect to the neck the incision lines are curved medially until sufficient looser the tissues is attained for the advanc of the flap. Figure 888 shows a case of h trophic scar tissue in the lower part face in which the choice of an advance flap is indicated because of the fulln

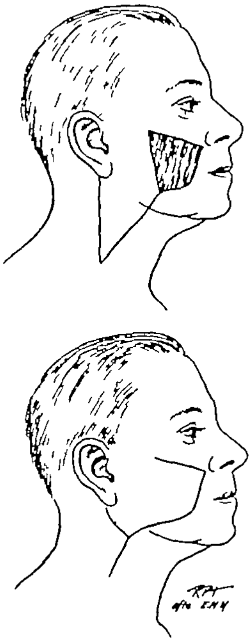

FIG 885. A large skin defect of the cheek, repaired by a transposed flap from the side of the face and neck.

the neck tissue and also because of the presence of a linear scar on the side of the neck. Such conditions emphasize the importance of preoperative planning

The case illustrated in Figure 889 again demonstrates the applicability of neck skin for the repair of the lower portion of the face The location of the defect in this illustration differs from those seen in Figures 885 and 886 It will be observed that the design of the flap is planned in accordance with the location of the defect. Whereas in Figure 885 the flap was designed to be shifted anteriorly and in Figure 888 the outline of the flap made possible its upward advancement the design of the flap in Figure 889 was planned to permit the upward and backward shifting of the flap. A vertical incision made along the anterior border of the sternomastoid muscle is equal in length to that of the raw area to be covered (Fig 889) Another incision extends obliquely toward the lower border of the chin. The flap is separated from the underlying tissues, raised to its new position and sutured

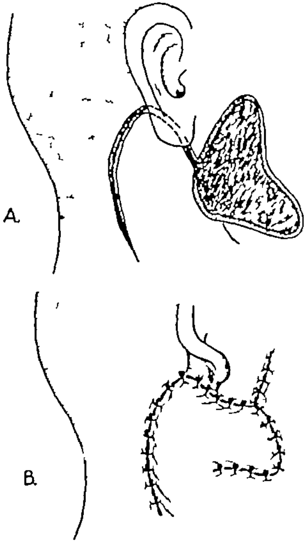

FIG 889

A Outline of postauricular flap for the repair of a defect over the angle of the jaw

B The postauricular flap has been transposed into the defect and sutured

A B

Fig 887

A. Photograph showing an irregular triangular shaped burn scar on the side of the face.

B. Result obtained by a postauricular flap transfer eleven days postoperatively by the method illustrated in Figure 886

A B C

Fig 888

A. Photograph showing a large scar of the lower part of the face near the corner of the mouth resulting from an automobile accident. The scar was excised and the defect was closed by an advancement flap from the neck.

B and C. Appearance six months after operation, illustrating the applicability of neck tissue for the repair of the cheek and also the improved contour of the neck.

Fig 889 Large defect over the angle of the jaw and side of the face, repaired by a rectangular flap extending downward in front of the sternocleidomastoid muscle and vertically upward toward the chin. The flap was raised to close the defect, the donor area was approximated

FIG. 890. Closure of cheek defect by flap transposed from the cervical area

A. Outline of cheek defect and design of flaps.
B. Flap 1 transferred to cheek defect.
C. Closure of secondary defect by transfer of flap 2 and V Y method.

in position The triangular secondary defect below is usually closed by approximating the proximal and distal borders of the wound after freely undermining the skin edges. Such closure of secondary defects by direct approximation is feasible in the looser tissues of older individuals. Another example of this type of flap is shown in Figures 890 and 891

Massive Scars of the Face

This type of deformity is not uncommon following burns the scars sometimes extend from the infraorbital region the side of the

Fig 891

A. Lesion of the cheek requiring skin replacement.
B. Result obtained by transposed cervical flap as illustrated in Figure 890

nose and as far down as the lower border of the mandible.

The swinging rotation flap of Esser with modifications, is a useful procedure for the repair of such deformities (see Chapter 17) The line of incision usually extends vertically in front of the ear to the mastoid region and down the neck anteriorly to the hairline, as far as the supraclavicular region if necessary A horizontal incision 5 to 10 cm. in length is made through the loose skin of the neck the skin of both face and neck is then raised from the underlying structures, care being taken to follow the fascial plane When required these large flaps furnish sufficient skin to cover the greater portion of the face (see Fig 1121 Chapter 29) If it is not possible to extend the flap to cover the entire defect gradual advancement of the flap may be achieved by repeated partial excision of the scars. The incision line may be extended over the posteromedial aspect of the auricle to secure additional skin to cover the raw area in front of the ear If the donor area of such a flap cannot be closed by simple approximation a skin graft is applied in the least conspicuous location

Figure 892 is an example of this condition and illustrates the procedure employed for repair Large rotation flaps from the neck are limited in size in male patients, for when the flap is transferred to the zygomatic or infraorbital regions the presence of hair bearing skin may be an inconvenience in the case shown in Figure 892 this condition became evident after the tissues had healed

Emphasis has been placed on the use of pedicled flaps in preference to that of skin grafts in the repair of surface defects of the cheeks We have emphasized the advantages of local flaps because of the better color match and texture obtained from the use of neighboring tissues. This is particularly important in male patients for the use of local flaps of neighboring skin restores the continuity of the hair-bearing area. The use of skin grafts in defects of the side of the face is indicated when the shifting of skin flaps is not possible or is an impracticable procedure due to the poor quality of the neighboring skin Although the skin graft is not the method of choice, the judicious use of such grafts is of practical value in some cases if it is possible to employ full

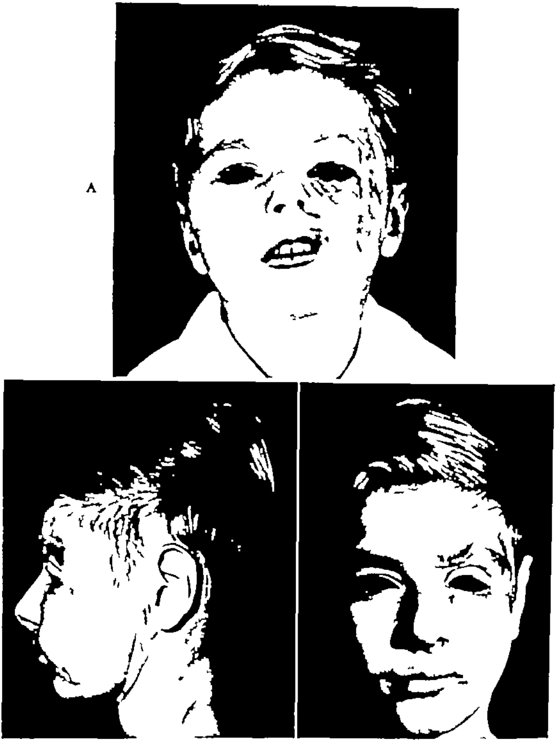

Fig 892

A. Photograph of child with conspicuous burn scars involving the greater part of the left side of face and the left side of upper lip.

B and C. A large rotation flap from the neck was transferred in three successive stages to cover the defect.

thickness grafts from the retroauricular and postaural areas, or from the supraclavicular region A good color match is obtained with such skin grafts of neighboring skin Skin grafts give good results in the parotid-masseteric and temporal regions. Over the zygomatic area and the rounded portion of the parotid where the skin overlies a thick layer

of subcutaneous tissue even a skin graft of full thickness does not provide sufficient bulk of tissue to prevent a flatness or depression in the repaired area. In such cases, the principle of shifting the defect can be employed. The cheek area is repaired by a rotation flap from the parotid-masseteric area and a full thickness retroauricular or supraclavicular skin graft is placed over the secondary defect in the parotid-masseteric area (Fig 878)

In extensive surface defects of the cheek, careful consideration will determine whether a free split thickness graft is preferable to a pedicled flap transferred from a distance. In some scarred burned cases, free split thickness grafts afford better results than distant pedicled flaps in others, particularly if a defect involves the neck, a distant flap is a more satisfactory type of repair It is not possible to be dogmatic as to the choice of free grafts or pedicled flaps *each case must be considered individually the choice of method and quality of the final result depending upon the judgment of the surgeon*

Full Thickness Defects of the Cheek

The reconstructive problem becomes more complex when both the inner lining and the outer covering of the cheek require restoration In such cases, two superimposed flaps are utilized one for the inner lining and the other for the covering Because of the elasticity of the oral mucosa it is often possible to obtain sufficient mucosal lining from the area adjacent to the defect. Sufficient mucosa to form the inner lining is often available along the wound edges of healed full thickness defects of the cheek, especially in traumatic cases. A considerable surface area of mucosa may be everted into the wound (Fig 893*A* *B*) The outer covering of the defect is provided by a skin flap from below the defect and from the neck (Fig 893*C*) The inner lining must also be provided by means of a flap of skin if enough mucosa is not available (Fig 894)

The choice of local or distant flaps is determined by the location of the defect and the availability of the surrounding tissues.

Two delayed flaps may be prepared if the lower part of the face is hairless, one from the skin below the defect, and a second larger flap from the skin of the neck as shown in Figures 895 and 896 After two weeks the first flap is turned in to form the inner lining of the defect, and the second larger flap employed to provide the outer covering

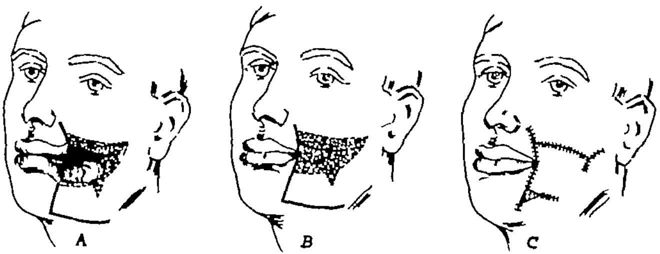

Fig 893

A. Diagram showing the defect of the side of face and the lines of incision for the repair of the condition shown in Figure 894

B. Buccal mucosa sutured to form the inner lining of the mouth, and to reform the corner of the mouth.

C. A skin flap raised from below to cover the defect.

A B

FIG 894

A. Photograph of patient with full thickness mucocutaneous loss of tissue of the side of the face including the corner of the mouth.

B. Result obtained upon completion of procedure outlined in Figure 893

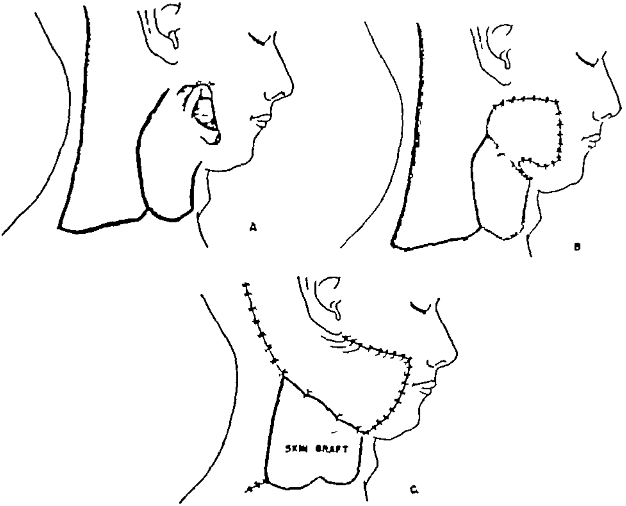

FIG 895

A Diagram showing two delayed flaps from the neck to repair a full thickness defect of the cheek Lack of hair makes this procedure practical

B Two weeks later the anterior flap was turned in to form the inner surface

C The posterior flap placed over the anterior flap the defect on the neck replaced with a skin graft

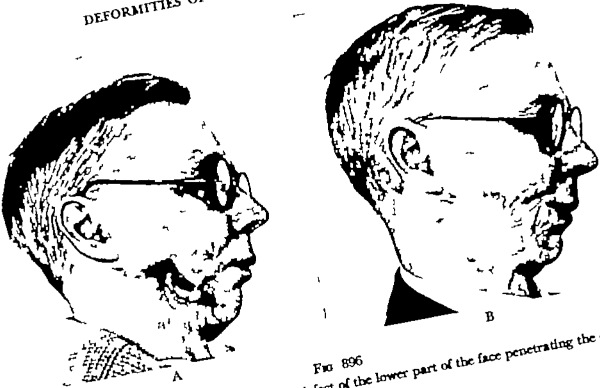

Fig 896

A. Photograph showing patient with a large defect of the lower part of the face penetrating the oral cavity
B. Result obtained by procedure described in Figure 895.

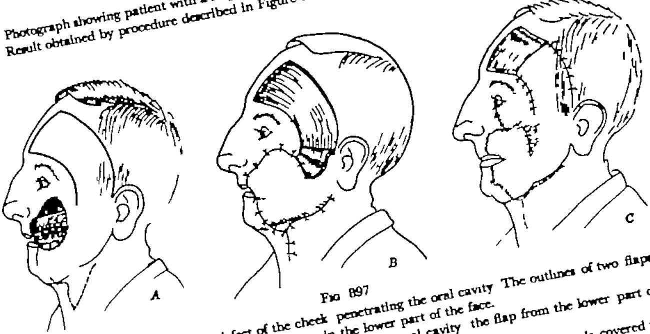

Fig 897

A. Diagram showing a large defect of the cheek penetrating the oral cavity The outlines of two flaps are shown, one in the temporal region and the other in the lower part of the face.

B Temporal flap brought down to form the lining of the oral cavity the flap from the lower part of the face is brought up to form the outer covering of the face

C. Two weeks later the unused part of the forehead flap is replaced The forehead defect is covered with a full thickness post auricular free graft the upper border of the cheek defect is closed.

The flap for the inner lining in male patients is extended downward in the neck into non-hair bearing skin the pedicle of the flap is severed in a later stage, the hair bearing portion of the flap being returned to its original site the non hair bearing skin furnishes the inner lining of the defect

When reconstructing defects which involve the corner of the mouth and the cheek (Fig 897) a flap can be elevated from the non hairy section of the temporal region to form the inner lining, while a large rotation flap from the side of the face is shifted to cover the outer surface of the defect (Fig

897*A B*) A second operation is required to sever the pedicle of the flap and to return the unused portion to its original location (Fig 897*C*)

A tubed pedicled flap from a distant donor area may be transferred to close the defect if flaps from the facial area cannot be employed Such a distant flap is usually

A B C

D E F

Fig 898

A Photograph of patient injured while working in an airplane factory The loss of tissue was greater than is apparent in the photograph.

B Scapular tubed pedicled flap Such a flap was necessary to supply tissue at the side of the nose the inner lining and the outer covering of the face

C. Distal end of the tubed flap transferred to the face

D Photograph following transfer of the skin supplied by the tubed pedicled flap

E and F Result following trimming and excision of excess tissue

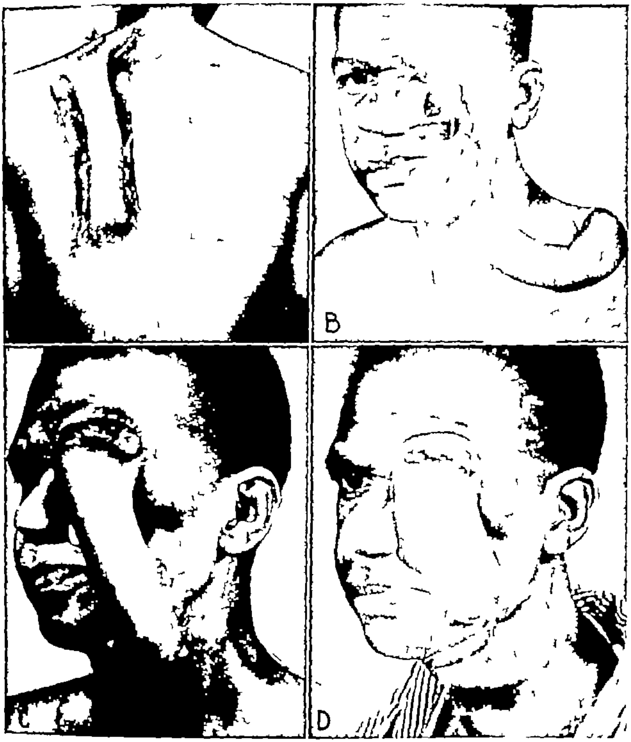

FIG 899 Repair of facial defect by scapular tubed pedicled flap (see also Figs 900 and 901)

A. Tube raised over scapular area. The donor area of the flap was skin grafted.

B. The lower end of the scapular flap was detached from the back and implanted into the submandibular area.

C. The upper end of the scapular flap is inserted into the supraorbital area.

D The tube is shortened and the lower end is implanted below the lower border of the facial defect.

(Figs. 899 to 901 from R. M. Campbell and J M. Converse, Plast. & Reconstruct. Surg., in preparation)

indicated when a large part of the face has been destroyed. Figure 898 shows a patient injured in an airplane factory who suffered fractures of the mandible and maxilla a large section of the left side of the face was also destroyed which included the left side of the nose A tubed pedicled flap from the scapular region was utilized in the repair of the left side of the face as illustrated in Figure 898

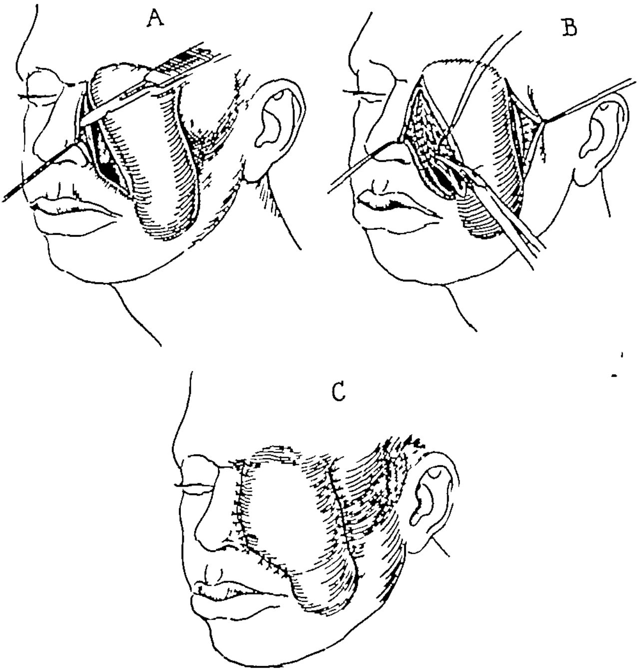

FIG. 900. Technical details of the implantation of the tubed flap into the defect
A. The edge of the defect is divided into inner and outer layers. The tube is incised longitudinally
B. Suture of the posterior edge of the defect to the posterior layer of the tube
C. Suture of the outer layers completed.

Repair of another large facial defect by a tubed pedicled flap transferred in stages from the scapular area is shown in Figures 899 900 and 901

DEFORMITIES OF THE CERVICAL AREA

Neck Contractures

Full thickness loss of skin following burns usually results in scar contractures of the neck. The looseness of the skin of the neck favors wound contraction during healing. The extent of deformity varies with the amount of skin destruction and the adequacy of early skin replacement by skin grafting. Web-like vertical bands of scar tissue pull the chin downward in some cases disturbing the normal contour and limiting neck movements. The chin may be bound to the chest by a mass of scar tissue when loss of skin is extensive

Fig 901

A. Appearance of patient with large orbitomaxillary defect.
B. Appearance after filling the defect with the tubed pedicled flap
C. Patient wearing black patch over the defective orbit (See also Fig 899.)

Fig 902. Extensive median scar contracture of the neck, resulting from burns in childhood. The alveolar process of the mandible has been pulled downward and forward resulting in a prognathic-like deformity (From V H Kazanjian, Am. J Surg 43 249 1939)

Secondary deformities of the soft tissues, due to extensive scar contractures of the neck, may include a downward pull of the corners of the mouth lower lip cheek tissues, and in extreme cases even the lower eyelids The bony structures may also be affected when contractures, originating during childhood remain uncorrected for a long period of time deformity of the mandible may result from the downward pull of the scar (Fig 902) The continued downward and forward pull on the neck has been

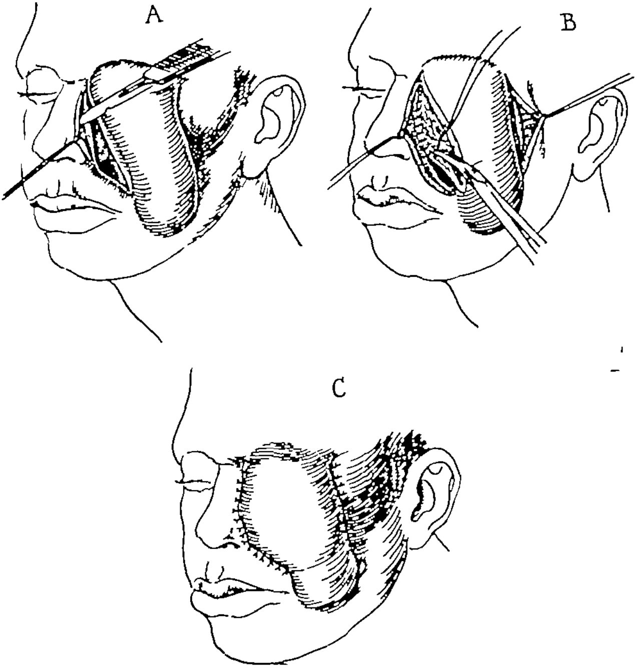

FIG. 900 Technical details of the implantation of the tubed flap into the defect
A. The edge of the defect is divided into inner and outer layers. The tube is incised longitudinally
B. Suture of the posterior edge of the defect to the posterior layer of the tube.
C. Suture of the outer layers completed.

Repair of another large facial defect by a tubed pedicled flap transferred in stages from the scapular area is shown in Figures 899 900 and 901

DEFORMITIES OF THE CERVICAL AREA

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Fig 901

A. Appearance of patient with large orbitomaxillary defect.
B. Appearance after filling the defect with the tubed pedicled flap
C. Patient wearing black patch over the defective orbit (See also Fig 899)

Fig 902. Extensive median scar contracture of the neck, resulting from burns in childhood The alveolar process of the mandible has been pulled downward and forward resulting in a prognathic like deformity

(From V H Kazanjian, Am J Surg 45 249 1939)

Secondary deformities of the soft tissues, due to extensive scar contractures of the neck may include a downward pull of the corners of the mouth lower lip cheek tissues, and in extreme cases, even the lower eyelids. The bony structures may also be affected when contractures, originating during childhood remain uncorrected for a long period of time deformity of the mandible may result from the downward pull of the scar (Fig 902) The continued downward and forward pull on the neck has been

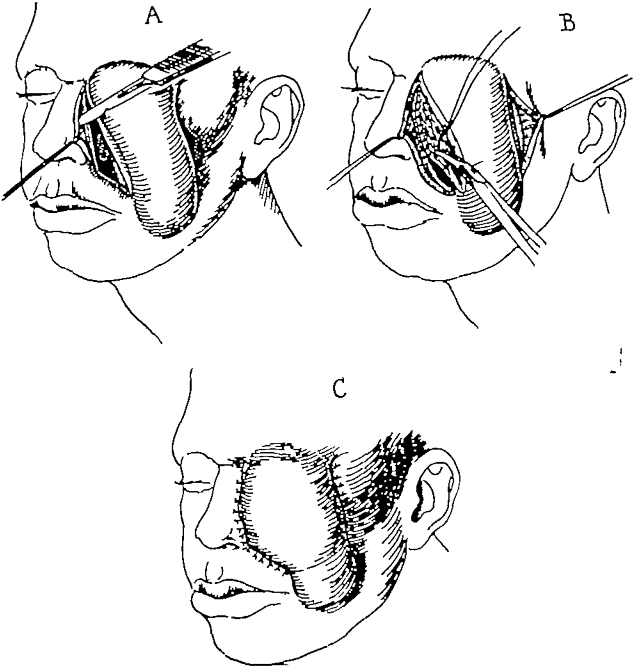

FIG. 900. Technical details of the implantation of the tubed flap into the defect

A. The edge of the defect is divided into inner and outer layers. The tube is incised longitudinally

B. Suture of the posterior edge of the defect to the posterior layer of the tube.

C. Suture of the outer layers completed.

Repair of another large facial defect by a tubed pedicled flap transferred in stages from the scapular area is shown in Figures 899 900 and 901

DEFORMITIES OF THE CERVICAL AREA

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FIG 901

A. Appearance of patient with large orbitomaxillary defect.
B Appearance after filling the defect with the tubed pedicled flap
C. Patient wearing black patch over the defective orbit (See also Fig 899)

FIG 902. Extensive median scar contracture of the neck, resulting from burns in childhood The alveolar process of the mandible has been pulled downward and forward resulting in a prognathic like deformity (From V H Kazanjian, Am. J Surg., 43 249 1939)

Secondary deformities of the soft tissues, due to extensive scar contractures of the neck, may include a downward pull of the corners of the mouth lower lip cheek tissues, and in extreme cases, even the lower eyelids. The bony structures may also be affected when contractures, originating during childhood remain uncorrected for a long period of time deformity of the mandible may result from the downward pull of the scar (Fig 902) The continued downward and forward pull on the neck has been

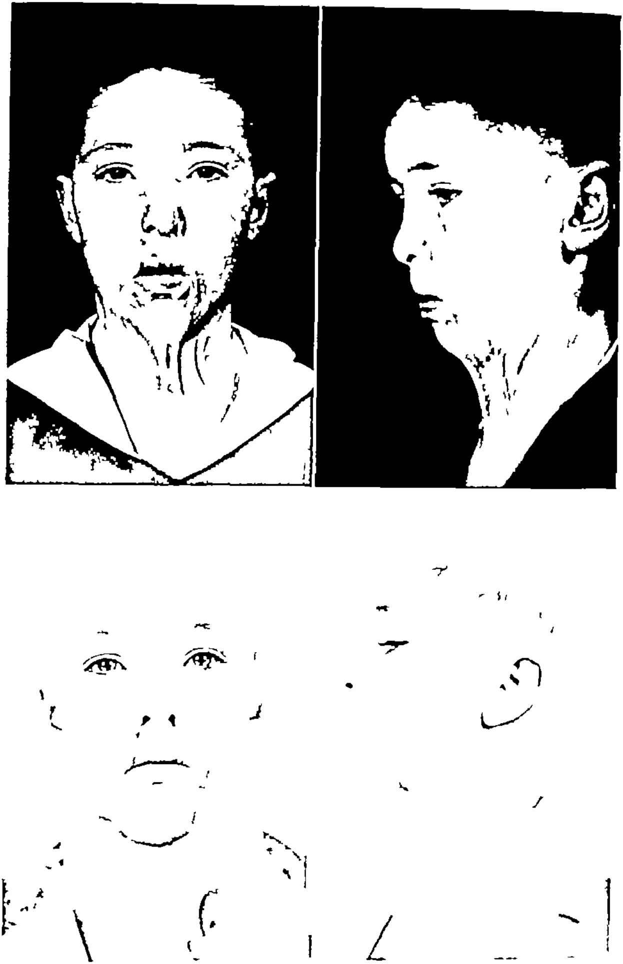

FIG. 905. (*U*) Photographs sh and neck burn (*Lower*) ob- tained follc technique III 906

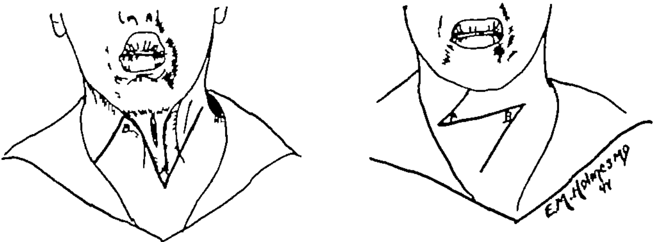

Fig 906. Web scars of the neck relieved by Z plasty (From V H. Kazanjian, Connecticut State M. J., 8 661 1944)

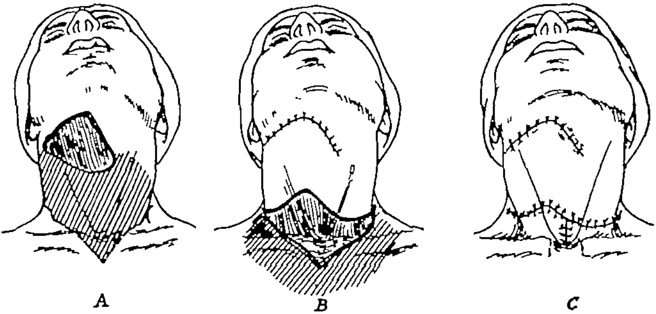

Fig 907 Diagrams showing a bipedicled flap advanced to cover a defect of the neck after removal of scars

A and B. The defect closed by raising a bipedicled skin flap from the lower part of the neck.

C. The secondary defect closed by approximation of the skin borders. The lined area in (A) and (B) was undermined.

quired and are obtained from the adjacent cervical or supraclavicular anterior thoracic, or scapular regions. The choice of the area depends upon the location and extent of the contracture, and also upon the condition of the surrounding skin. A flap of skin taken from the base of the neck or the supraclavicular and anterior thoracic areas is readily shifted into the defect (Figs. 908 and 909) A large rectangular flap often suffices to cover the anterior aspect of the neck if it is not of sufficient size an additional flap from the opposite side of the neck provides the required surface of skin (Fig 910)

When the skin of the chest is covered with scars a fairly common condition in burn cases, a flap can be procured from either the acromial or scapular region. Such a flap is not as easily shifted as one from the thoracic wall but it has the advantage of being free of scars. Figure 911 shows extensive burn contracture of the neck and also marked pull on the lower lip the operative procedures in this case follow

Fig 908. Outline of rectangular flap for the repair of a burn contracture of the neck.

A flap was outlined in the healthy tissue on the right side of the neck, lateral to the contracture a similar flap was made on the left side of the neck these two flaps were advanced and joined in the mid line. A defect of the lower part of the neck and chest was covered with a skin graft Figure 912*A* *B* shows the result following the first operation. The median contracture of the neck was excised in a second operation a few months later The skin of the right side of the neck was undermined freely and advanced toward the mid line. A flap from the left acromial region (Fig 913) was transposed to join the flap from the right side. The secondary defects on the chest and shoulder were covered with skin grafts. Figure 912*C* *D* shows the result obtained by the second operation

The median scar joining the flaps was ex

A B

Fig 909

A Burn contracture involving the greater part of the face and neck This severe injury was caused by the burning of a *Halloween mask worn on the face*

B Repair of neck contracture following transfer of the flap illustrated in Figure 908. The secondary defect on the chest was covered by a skin graft Other facial deformities were corrected by additional operative procedures

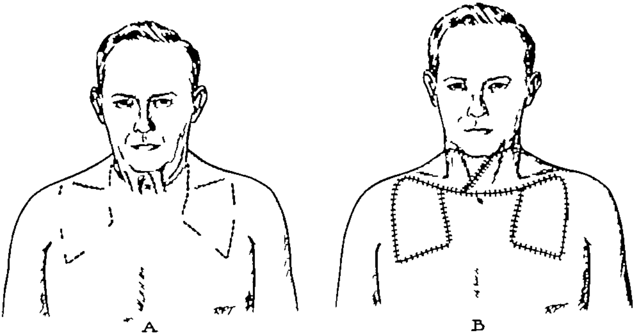

Fig 910

A Outline of bilateral chest flaps for repair of cervical contracture.

B Transfer of flaps to the neck defect. Secondary defects covered by skin grafts. Note oblique suture line of the flaps to minimize contraction.

cised (Fig 914*A*) in a subsequent operation The two neck flaps were further advanced and joined along a broken line in order to eliminate the vertical median scar (Fig 914*B* *C*)

Two defects remained after the flaps were joined one of the defects, shown in Figure 914C resulted from excision of scar tissue causing ectropion of the lower lip the other is shown in the same figure at the base of the neck on the left side. These defects were corrected by split thickness skin grafts (Fig 914*C*) Figure 911 shows the result following the final operation.

Another method for repair of extensive contracture of the neck consists of utilizing flaps from the scapular region An abundant amount of skin can be transferred to the neck from this area the skin of the scapular region however is not as thin and flexible as that from the chest

A patient in whom the skin over the chest is scarred and cannot be utilized is shown in Figure 915*A* A scapular delayed flap was employed to cover the neck defect (Fig 916) Figure 915*B* shows the result achieved by this method

If outlined flaps are too long in proportion to their width they should be delayed. It is difficult to make actual measurements of the size of the flap to be used in delayed flaps but a safe rule is to outline a slightly larger flap than is required.

The use of delayed flaps is indicated particularly when the greater part of the neck is to be repaired. If a flap from one side is not sufficient to cover the defect, bilateral flaps from these areas supply an abundant amount of tissue for the repair of the neck. When bilateral flaps are used however their outline should be planned in such a way that the line of suture crosses the neck diagonally rather than vertically for a vertical line is more likely to form a contracted web although the web may be corrected at a later date by a Z plastic operation if necessary The donor areas of the flaps should be covered by split thickness skin grafts.

Tubed Pedicled Flaps

Flaps from a distant donor area usually in the form of tubed pedicled flaps are required when a large amount of skin is required to relieve the neck contractures. The

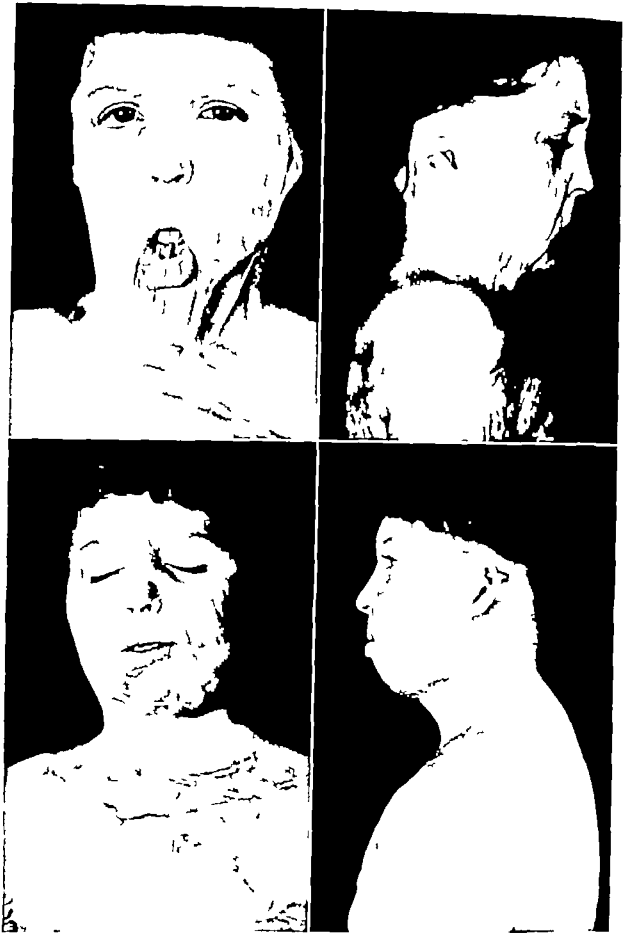

Fig 911 (*Upper*) Photographs showing severe contracture of the neck resulting from massive loss of skin following burn. The chin is bound down to the chest by scar tissue (*Lower*) Result obtained by surgical procedures described in Figures 912 to 914

FIG 912. Intermediary stages of case shown in Figure 911
A and B. The result following the advancement of two lateral flaps described in the text.
C and D Result obtained following transfer of acromial flap illustrated in Figure 913

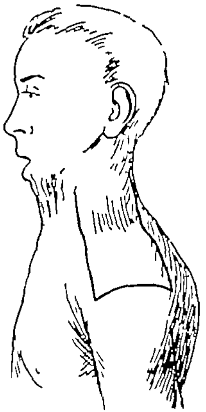

FIG 913 Outline of acromial flap for transposition to neck defect.

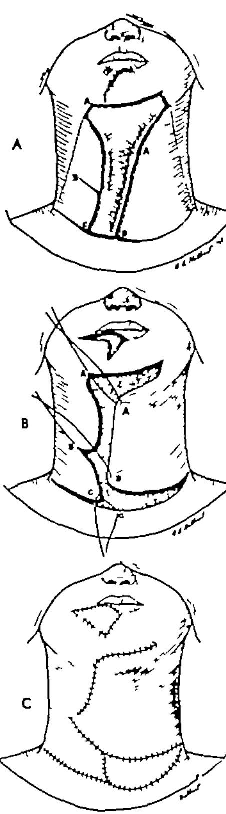

FIG 914

A. Incision lines for removal of contracted median scar

B Neck flaps prepared for transfer

C. Flaps joined along a broken line in order to eliminate the vertical median scar The secondary defects are covered by skin grafts

upper portion of the chest, the abdominal wall or the scapular region serve as donor areas for the flaps.

The acromio-pectoral flap because of its proximity to the defect, is the most readily transferred tubed pedicled flap when a moderate amount of skin is required. After the flap has been raised the donor area should be skin grafted to avoid closure under tension.

Large tubed pedicled flaps may be transferred from the scapular region (Figs. 917–919) These flaps are more advantageous than the abdominal tubed pedicled flap because the scapular flap may be transferred without the need of the more complicated indirect transfer This transfer includes a preliminary implantation on the wrist or forearm and the inconvenient position which must be maintained by the patient due to the mobilization of the upper extremity when the flap is carried to the neck The utilization of a large tubed pedicled flap from the scapular region is shown in

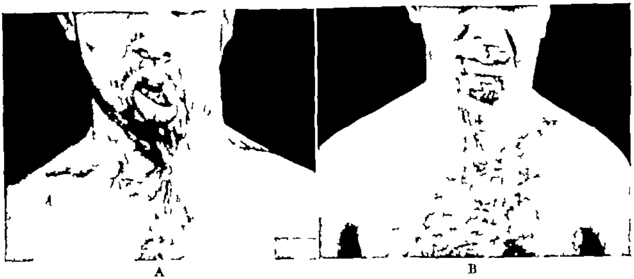

Fig 915

A. Severe cervical contracture resulting from burn.
B. Result obtained by procedures illustrated in Figure 916

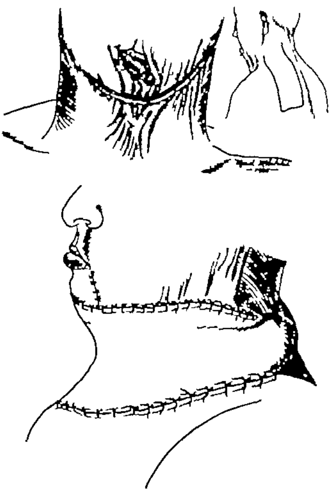

Fig 916

A. Diagram showing incision line to release neck contracture.
B. Outline of scapular flap.
C. Scapular flap transposed to neck defect.

Figure 917 The intermediate step and final result are shown in Figure 918 Another case is illustrated in Figure 920

Large oblique abdominal tubed pedicled flaps may be raised in one stage. The pedicle is constructed in two stages when a unusually long tubed pedicled flap is required *One extremity of the flap is severed and* attached to the wrist or distal portion of the forearm The other extremity is severed in *a later stage and is then opened and attached* to a portion of the neck defect. The wrist attachment is severed in a still later stage, and the remainder of the flap is opened and inserted into the cervical defect. In unusually long tubed pedicled flaps, the portion of the flap or wrist attachment may be inserted into the lateral aspect of the cervical region in a preliminary step prior to the opening of the remainder of the flap

The inconveniences of the tubed pedicled flap method are the length of time and the multiplicity of operations required from the time of construction of the tube to its final insertion into the neck defect. Non tubular direct pedicled flap repairs are completed in less time. The tubed pedicled flap however is a safe method when properly designed and carefully executed some of our best

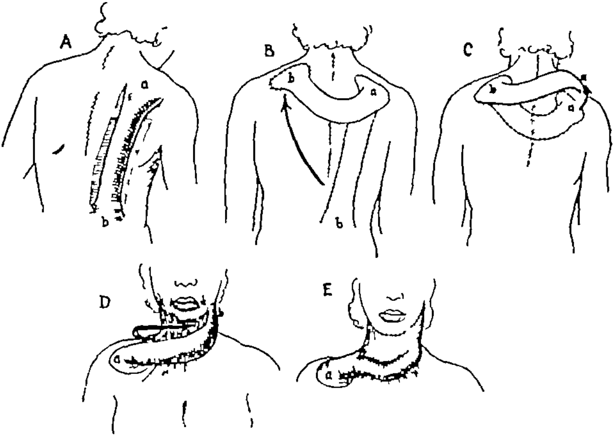

FIG 917 Transfer of scapular tubed pedicled flap to the neck

A. Large scapular tubed pedicled flap.

B. The lower end (B) of the flap is transferred to the upper portion of the left scapular area.

C. The upper end (A) of the tubed pedicled flap is transferred to the right supraclavicular area.

D The extremity (B) of the tubed pedicled flap is transferred over the right shoulder to the anterior aspect of the neck being implanted into the left side of the neck.

E. The flap is opened and is spread over the neck.

(Figs. 917 918 and 919 from R. M Campbell and J M Converse Plast & Recons. Surg in preparation)

FIG. 918. Repair of burn contracture of the neck by scapular tubed pedicled flap.

A. Appearance of patient prior to operation.

B. Postoperative result obtained

final results have been obtained by this method

After covering the defect by a tubed pedicled flap as after all flap repairs a number of operations are required to diminish the thickness of the subcutaneous fatty layer in order to improve the contour A defect which is common to all flap repairs of the neck is the obliteration of the cervical angle usually located immediately above the thyroid cartilage It is sometimes advisable to make a horizontal incision through the flap at this level and to insert a free split thickness graft to restore the angle

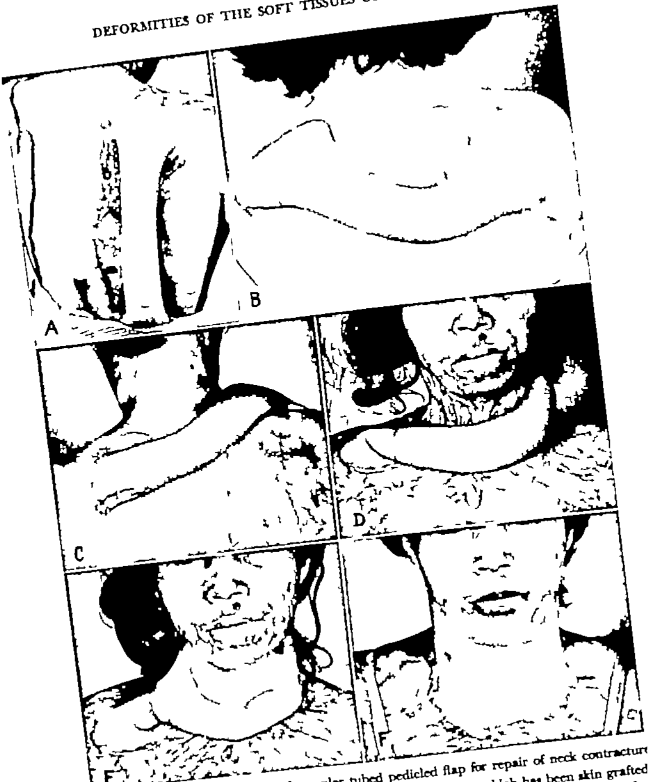

Fig 919 Technique of transfer of scapular tubed pedicled flap for repair of neck contracture
A. Appearance of tubed pedicled flap Note the donor site of the flap which has been skin grafted
B. First stage of transfer after lower end of the flap is placed into the upper portion of the left s
area.
C. The right extremity of the flap has been moved forward and implanted into the right suprac
area.
D The portion of the flap previously implanted into the left scapular area has been detached a
planted anteriorly into left side of the neck.
E Appearance of flap after it was opened.
F Result obtained after the entire flap was spread over the neck and subsequent operations to r
excess adipose tissue from under the flap (see also Fig 918A)

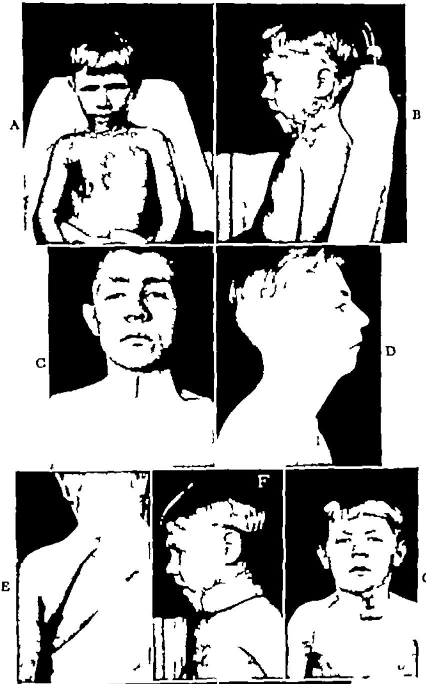

Fig. 920

Skin Grafts

Skin grafting is employed to cover second ary defects on the chest, the lower part of the neck and also the scapular region after flaps have been shifted from these areas to cover the defects of the neck.

Split thickness skin grafts, rather than pedicled flaps have also been employed to relieve neck contractures. The success of free grafting depends upon complete survival of transplanted skin and prevention of con traction.

The neck should be placed in hyperex tension in order to increase the surface of the recipient site and to cover it with a maxi mum surface of skin The introduction of a large surface of grafted skin minimizes sub sequent contraction It is obvious that if a high percentage of survival of the skin grafts is not assured, secondary contraction of the resulting raw areas favors the recurrence of contracture.

The success of skin grafts in a mobile area such as the neck requires immobilization of the region during the healing period of the skin grafts Immobilization of the neck is achieved by a number of methods. The most commonly employed is a bulky pressure dressing, immobilized by bandages, placed circumferentially around the neck, beneath the axilla and around the chest. Another method consists of immobilizing the neck by means of Minerva-type plaster encase ment this type of splint provides even more effective immobilization of the cervical re gion.

Progressive contraction of skin grafts dur ing the weeks and months following success ful grafting has been the most discouraging aspect of this technique. Such late contrac tion can be minimized by thick split thick ness grafts. It is also minimized by splinting the neck in extension an elastic bandage collar or an orthopedic type collar (Fig 921) should maintain the neck in extension for a period of at least six months.

FIG 921 Orthopedic collar to maintain neck extension following repair of burn contracture of the neck by means of skin grafts (courtesy of Dr Thomas D Cronin)

Skin grafts are not uniformly successful the subsequent contraction may be exten sive but they are indicated when pedicled flaps are not available because of scars on the chest or other areas from which pedicled

FIG 920

A and B. Photographs showing cervical scar contracture following burn The chin is adherent to the chest.

C and D Late result obtained following replacement of scarred skin by transferred scapular tubed pedicled flap as shown in E, F and G The skin surface was sufficient to permit extension of the neck the patient re fused further surgery for the elimination of the median groove in the flap.

E. Scapular tubed pedicled flap.

F The distal end of the tubed pedicled flap is inserted into the left side of the neck.

G The proximal end of the tubed pedicled flap is inserted into the right side of the neck.

H and I Early result obtained following spreading of the tubed pedicled flap and inserting it into the cer vical area

(From V H Kazanjian New England J Med. 215.30 1936)

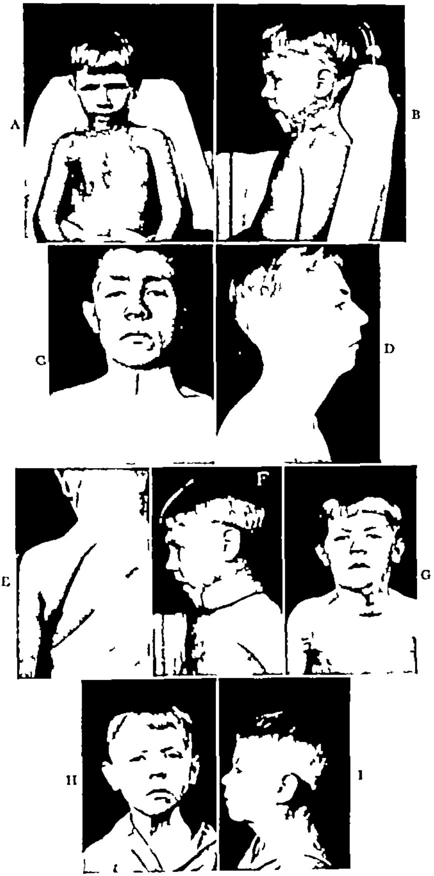

Fig. 940

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Skin grafting is employed to cover secondary defects on the chest the lower part of the neck and also the scapular region after flaps have been shifted from these areas to cover the defects of the neck.

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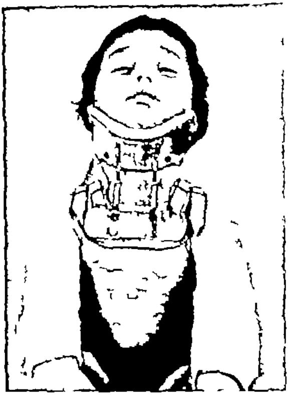

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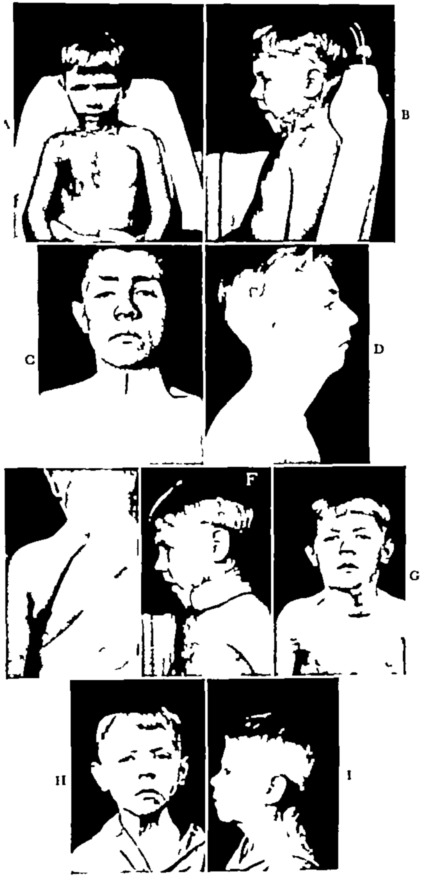
(From V H. Kazanjian, New England J Med. 215 50, 1936)



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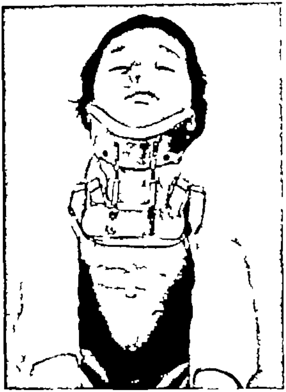

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H and I Early result obtained following spreading of the tubed pedicled flap and inserting it into the cervical area.

(From V H. Kazanjian, New England J Med., 215 30 1936)

A B

C D

Fig. 97

A and B Photographs showing the result of extensive deep burns involving the neck and chest. At the initial operation a skin graft was used to cover the chest defect. Repeated skin grafting operations were necessary to relieve the contracture of the neck.

C and D Photographs of patient four years after operative treatment to relieve contracture of the skin of the neck.

flaps are usually available. The addition of skin is often required after a period of six months in order to offset secondary contracture a thick split thickness skin graft should be used.

The most favorable area in the neck for a free graft is the suprahyoid area for a relatively firm base is provided by the underlying musculature. A thick split thickness graft or even a full thickness graft may be successfully grafted in this area such a graft is sufficiently thick to avoid contraction.

Figure 922 illustrates a case in which repeated skin grafting of the neck was combined with an advancement flap from the side of the neck.

24

DEFORMITIES OF THE JAWS

Deformities of the jaws may be classified into three groups

1 Developmental malformations due to injury of the bone at birth or during the period of growth.

2 Deformities due to malunited fractures.

3 Deformities due to loss of bone or soft tissues

DEVELOPMENTAL MALFORMATIONS OF THE JAWS

Developmental malformations of the jaws are attributed either to faulty development in the embryo or to the effects of trauma or disease or other unclarified causes upon growth centers in postnatal life. Faulty development as a result of injury is particularly marked in the mandible injury occurring in early life resulting in a greater degree of deformity Because of the intimate relations of the facial bones, arrest of growth of one bone may result in the distorted growth of others thus the zygoma and *the orbit are often underdeveloped* when growth of the maxilla is arrested Factors which influence growth of the jaws are discussed in Chapter 12.

Deformities may affect one or more portions of the jaw the tooth-bearing area the denser bone of the body the ascending ramus or the mandibular condyle Malocclusions of the dentition are usually the aftermath of malformations which affect the dentoalveolar components.

Classification of Jaw Malformations

The term *prognathism* has been defined as a condition in which the lower jaw protrudes and the mandibular teeth are anterior to those of the maxilla (Fig 923A) The upper jaw may also be prognathic. When both maxilla and mandible are prognathic, the condition is referred to as bimaxillary prognathism *Retrognathism* mandibular retrusion describes a condition in which the mandible is retruded and the lower teeth are lingual to those of the maxilla In extreme cases, as exemplified in *developmental malformations due to temporomandibular* ankylosis marked atresia of the mandible results in a typical bird like appearance of the face Deviation of the chin to one side due either to unilateral lack of development or more infrequently to over development of the jaw due to condylar hyperplasia results in a deviation from the mid-sagittal plane and a cross-bite such a condition may be designated by the term *laterognathism* These malformations also include such dental occlusal variations as over bite under bite open bite or cross bite

Facial Diagnosis

In addition to the clinical examination full face and profile photographs are taken in accord with the Frankfort horizontal and mid-sagittal plane of the skull (see Chapter 11) Horizontal lines on the full face photograph passing through trichion nasion and subnasale divide the face into approximately three equal parts. Increase or decrease in the vertical dimension of the lower third of the face may be of significance in diagnosis. The mid-sagittal plane of the face is useful in determining facial asymmetry and in defining deviations from the mid line

The study of the profile is helpful in establishing relationships between the lower and middle portions of the face. Two perpendiculars to the Frankfort horizontal may be placed on the profile photograph as recommended by Izard (1943) one tangent to the glabella or anterior frontal plane (Fig 923) and the other suggested by Simon (1943) extending downward from orbitale.

Cephalometry

The development of standardized cephalometric roentgenograms has emphasized the importance of relating the teeth and their supporting structures to the face and skull in the diagnosis of malocclusion These techniques, described in Chapter 14 offer a dynamic approach to the study of growth in the living rather than the measurements of the dry skull previously employed in anthropometry

Oral Diagnosis

Clinical examination and a study of plaster casts of the dentition aid in determining the type of dental malocclusion and in planning corrective treatment Casts of the dentition serve as a record of the original condition and also as "working casts two sets of dental casts are therefore made for each case. When planning the surgical correction of malocclusion the working casts are articulated and then cut to simulate the separation of the bone immediately following sectioning of the jaw (Fig 924) The extent of the displacement of the fragments is evaluated preoperatively in this manner thus facilitating the plan of osteotomy and design of the appliance for immobilization

Preoperative Planning

Each case is planned in relation to the individual problems to be considered. Because treatment usually involves surgical separation of skeletal portions of the jaws the planning must include means of fixation of the separated parts. Also to be considered is the action of the muscles of the jaws upon separated fragments (see Chapter 6)

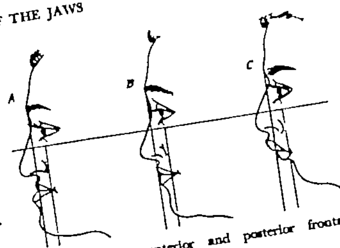

FIG 923 The anterior and posterior frontal planes (after Izard and Simon)

A. In mandibular prognathism the chin and lower lip protrude in front of the anterior frontal plane.

B. In the average profile the chin is situated between the anterior and posterior frontal planes.

C. In mandibular retrognathism the chin is situated behind the posterior plane.

(Figs. 923 and 924 from J M. Converse and H H. Shapiro Plast. & Reconstruct. Surg 10 473 1952)

Fixation Appliances

Fixation appliances are essential to achieve immobilization of separated fragments in their proper relationships following surgery Such appliances should be as simple as possible and be designed to permit a degree of flexibility for adjustments are required on the operating table because the lines of osteotomy or the amount of excised bone are often at variance with the preoperative plan Rigidly conceived mechanical appliances constructed on the anatomical articulator cannot be relied upon for complete accuracy it is for such reasons that one must be prepared for adjustments of the appliances at the time of operation

When preparing corrective procedures, prominent or interfering cusps of teeth as indicated on the articulated dental casts, are reduced by grinding in order to obtain optimal cuspal relationships and balanced occlusion following surgery The success of such surgical procedures as sectioning the ramus or body of the mandible is dependent

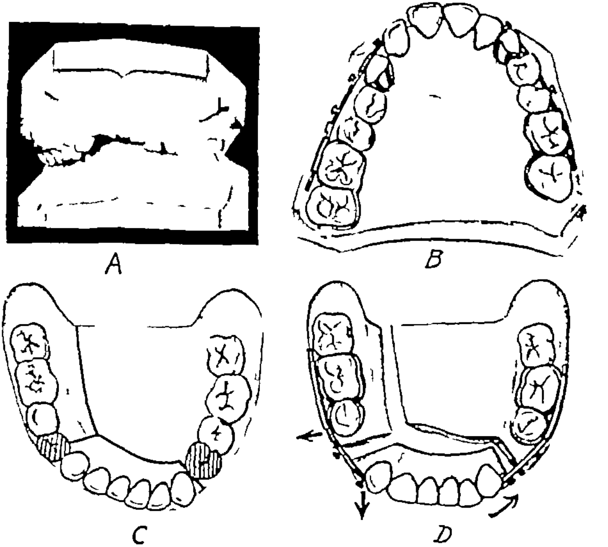

Fig 924 Planning osteotomy for malocclusion

A Plaster casts of the dentition showing malocclusion due to maldevelopment of the mandible

B Cast of the maxillary teeth showing the design of the appliance for intermaxillary fixation following osteotomy

C Cast of the mandibular dentition The shaded teeth are to be extracted The cast will be cut along the indicated lines in order to plan the correction

D Sectioned cast showing the extent of the proposed displacement of mandibular fragments to be achieved by bilateral osteotomy also the fixation appliance

upon the maintenance of adequate postoperative occlusion When such a procedure is indicated it may sometimes be necessary to remove one or more teeth prior to osteotomy to permit preliminary healing of the alveolar bone

Appliances for the fixation of surgically separated segments of the jaws are similar to those described in Chapter 6 We favor the use of bands which are carefully adapted *and cemented to selected teeth Buccal tubes,* soldered to the outer surfaces of the bands, serve to anchor dental arch bars. The arch bars may be rounded on the buccal surface flattened on the lingual surface contoured to the teeth and wired to the dentition The bands are fitted to two or more adjacent teeth and welded together for better retention constituting a retentive unit capable of withstanding considerable stress without be-

coming loosened in the postoperative period of fixation (Fig 925 see also Fig 123 Chapter 6)

Orthodontic and Prosthetic Treatment

Orthodontic treatment is effective in correcting malocclusion when the cause is limited to abnormalities of the dentoalveolar segments of the jaws. Orthodontic treatment alone is not sufficient in developmental deformities which affect the body of the maxilla or the body or ramus of the mandible surgical interference is required to correct such gross malformations. Orthodontic therapy previous to surgery is at times essential to obtain improved dental relationship Orthodontic and prosthetic services are often *indispensable complements to surgery* both prior to and following surgical procedures for the correction of developmental malformations of the jaws

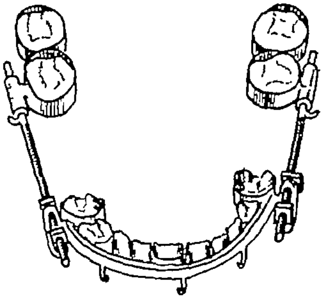

Fig 925 Arch and bar appliance constructed in three sections. Bands are fitted to teeth in each of the three sections. The posterior and anterior sections are joined by jack-screws permitting variations in the position of the anterior section (see also Fig 123 Chapter 6) The slot arrangement for the jack-screws permits flexibility

SURGICAL TREATMENT OF MANDIBULAR MALFORMATIONS

Mandibular Retrusion Retrognathism

Underdevelopment of the mandible which results in retrognathism, may be unilateral affecting only one ramus or the body of the bone, or bilateral the entire mandible being symmetrically underdeveloped bilateral underdevelopment is frequently referred to as mandibular atresia or micrognathia.

Such deformities are due either to arrested growth or are the result of trauma or infection in early life. They are frequently associated with ankylosis of the temporomandibular joint due to trauma during infancy and childhood. Injury of the temporomandibular joint in adult life unless followed by bone destruction does not result in mandibular deformity

Unilateral Mandibular Retrusion

Interference with growth of one side of the mandible due to unilateral injury or infection occurs more frequently than bilateral arrest of growth or atresia The affected side of the mandible is shorter the chin is deviated toward the shorter side and usually shows marked retrusion (Fig 926*A* *C*) The *unaffected side* of the mandible is flat and may appear to be the deformed portion of the mandible to an uninitiated observer (Fig 926*A*) Asymmetry of the lower portion of the face results from the deviation of the chin toward the short side of the mandible. The difference in length of the two halves of the body of the jaw when measured from the mid point of the chin to the mandibular angle, may be as much as 2 cm. The degree of deformity depends largely upon the age at which the injury to the growth center occurred the earlier the injury the greater the ensuing deformity The *external facial asymmetry* due to disproportionate growth of the two halves of the mandible is accompanied by disturbed dental occlusion such as retrognathism and frequently laterognathism or cross-bite When *teeth* are present on the affected side, they are *inclined* lingually in relation to the *upper* teeth. When the teeth are absent on the affected

FIG. [illegible]

A. Developmental malformation of the mandible due to arrested growth on the left side.

B. Result obtained following bilateral L-shaped osteotomy of the body as in Figure [illegible] and as planned in Figure [illegible] and restoration of contour by bone grafts introduced by the intraoral technique.

C. Preoperative profile view of the patient.

D. Postoperative appearance showing advancement of the mandible and contour restoration.

(From J. M. Converse and H. H. Shapiro, Plast. & Reconstruct. Surg. 10:473, 19[illegible].)

side, the loss is usually due to osteomyelitis in childhood.

Bilateral Mandibular Retrusion Atresia

The entire body of the mandible is symmetrically underdeveloped in bilateral retrusion or atresia. The chin is usually in the mid sagittal plane of the face and is in retrusion (Fig 927) The anterior teeth of the retrognathic mandible are posterior and lingual to the maxillary dentition In one of our cases, the condyles had no contact with the glenoid fossae, the mandible articulating with the skull by means of the coronoid processes (see Fig 955)

Injury to the condyle was sufficiently severe to produce temporomandibular ankylosis in most of our cases of mandibular atresia In the adolescent or adult, restoration of temporomandibular function is a necessary preliminary operative procedure before undertaking reconstruction of the atresic mandible (see Chapter 26) In the child, ankylosis is relieved as early as possible.

Treatment of Mandibular Retrusion

Surgical elongation of the short side of the body of the mandible in *unilateral retrusion* where a normal complement of teeth is present, restores adequate dental occlusion corrects the asymmetry of the halves of the mandible and improves the appearance of the retruded chin Bilateral elongation is required in the *bilateral retrusion* of mandibular atresia

Careful preliminary planning with working casts of the dentition is essential (see Fig 924) Carious teeth should be treated or extracted. Fixation bands and dental arch bars are prepared prior to osteotomy Additional contour restoring bone grafts are usually required either concomitantly with the osteotomy or in a subsequent stage, to

FIG 927 Bilateral retrusion of the entire body of the mandible The condition resulted from the kick of a horse in early childhood Bilateral ankylosis developed. The ankylosis was corrected on the right side five months later the left side was operated on. *Photographs* show symmetrical retrusion of the mandible as contrasted with deformities resulting from unilateral ankylosis.

correct the flatness of the unaffected side of the mandible and to increase the prominence of the chin

Because the problem of growth is not as yet completely understood, it seems advisable not to perform this operation in children until maximum growth of the mandible has occurred

It may be possible to correct the mandibular deformity by unilateral osteotomy of the body of the mandible in unilateral retrusion bilateral section however is required to restore adequate dental occlusion and to elongate the body of the mandible sufficiently on both sides in order to place the chin in the mid-sagittal plane The addition of bone grafts over the mental symphysis is usually required to further increase the projection of the chin after osteotomy and to correct flatness of the body of the bone

Technique of Osteotomy of the Body of the Mandible

In osteotomy of the body of the mandible through the intraoral approach oral contamination does not interfere with bony consolidation antibiotics are employed routinely in all these cases. When a submandibular incision is employed a scar at the site of the incision is of relatively minor importance in cases of marked deformity

Various types of osteotomy are employed The line of ostoetomy and its location in the body of the mandible varies according to the deformity and the patient's dentition.

The surgical problems involved in osteotomy of the body of the mandible include (1) maintenance of contact between the bony fragments to insure consolidation and (2) the preservation of the inferior alveolar neurovascular bundle

1 MAINTENANCE OF CONTACT OF THE BONE FRAGMENTS. The L-osteotomy (Fig 928A to D) or oblique osteotomy (see Fig 932) lines are preferable to the vertical line osteotomy because they afford greater surface areas of contact. Maintenance of contact between the fragments is assured by dental fixation appliances, or by direct interosseous or circumferential wiring If the surface contact between the bone fragments appears inadequate iliac bone grafts are placed in the line of osteotomy to insure consolidation

2. THE PRESERVATION OF THE NEUROVASCULAR BUNDLE. The mental foramen is the determining landmark for establishing the line of osteotomy The mental nerve branches from the inferior alveolar nerve at the mental foramen its terminal filaments innervating the soft tissues of the chin and lower lip The anterior portion of the inferior alveolar nerve continues through the body of the bone to the mid line this portion of the nerve known as the anterior inferior alveolar nerve innervates the teeth anterior to the mental foramen

When the vertical line of the step-osteotomy extends through the bone anteriorly to the mental foramen and the horizontal line below the inferior alveolar canal (Fig 928A to D) the inferior alveolar nerve is spared. Preservation of the anterior inferior alveolar nerve is feasible by decompressing the main trunk posterior to the mental foramen and extending the exposure of the canal anteriorly to the mental foramen (Fig 928 C H)

Gaps in the dental arch due to missing teeth offer a convenient site for the line of osteotomy avoiding the sacrifice of additional teeth This line may be located posterior to the mental foramen Continuity of the nerve is assured by the following technique the outer alveolar plate posterior to the mental foramen is removed by means of a motor-driven large round surgical burr or a gouge thus decompressing the nerve (Fig 929D)

Methods of Fixation

After the retruded body of the mandible is advanced following osteotomy fixation of the bone is essential until bony consolidation occurs. Adequate fixation is supplied by a band and arch bar appliance fastened to the maxillary dentition and a mandibular

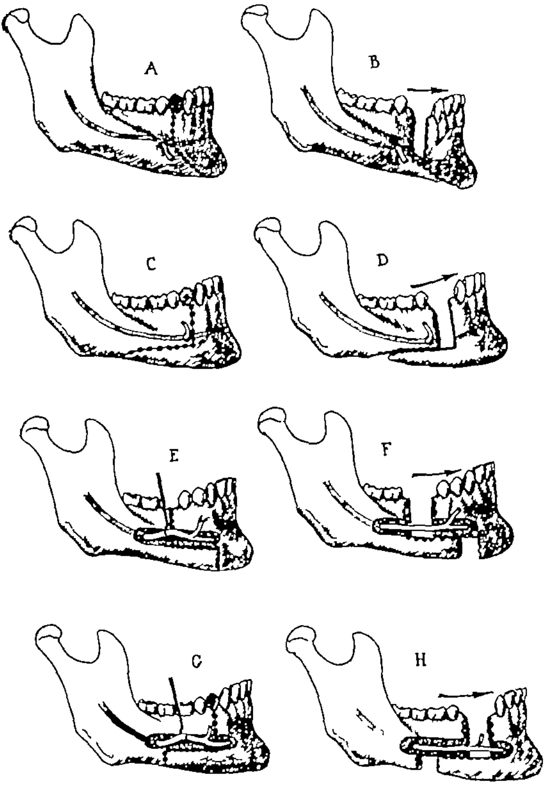

FIG 928. Four types of osteotomy lines

A. The L-osteotomy anterior to the mental foramen.
B. Elongation obtained by L-osteotomy
C. The reverse L-osteotomy a favorite technique for elongation of the body of the mandible.
D Elongation obtained by the reverse L-osteotomy
E. Step-osteotomy posterior to mental foramen with exposure of the inferior alveolar neurovascular bundle.
F Elongation obtained by step-osteotomy
G Reverse step-osteotomy anterior to mental foramen with exposure and preservation of the antero-inferior alveolar nerve.
H. Elongation obtained by reverse step-osteotomy

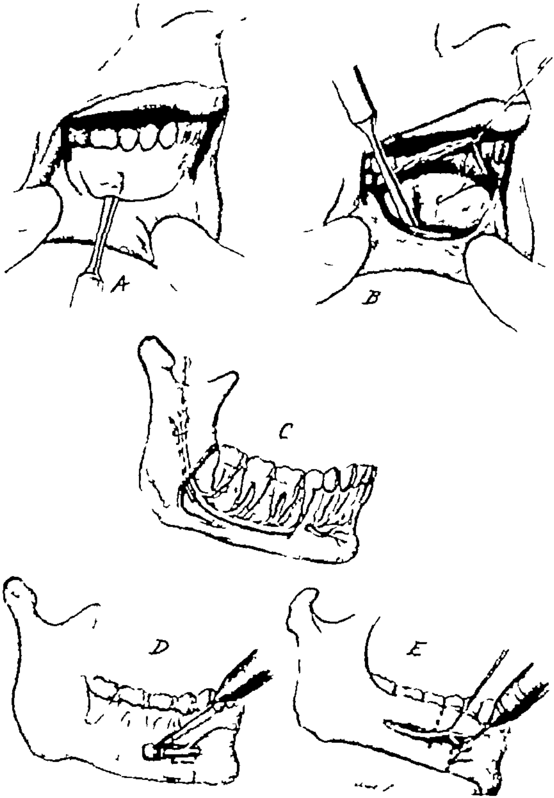

Fig. [illegible]. Technique of intraoral step-osteotomy of the body of the mandible.

A. Wide flap to expose the lateral aspect of the body of the mandible. The periosteum is being [illegible]ed.
B. The outer aspect of the body of the mandible is exposed; the branches of the mental nerve are preserved.
C. Drawing representing the inferior alveolar nerve trunk, showing the mental nerve and the antero-inferior alveolar branch (shaded).
D. The inferior alveolar canal is uncovered by removing the outer plate, thus exposing the neurovascular bundle.

fixation appliance, constructed in three sections (see Figs. 924 and 925)

In addition to the use of intraoral appliances, maximum forward displacement is obtained by employing an external traction apparatus which exerts a precise pull on the symphysis (Figs. 930 and 931) A circumferential stainless steel wire is passed around the symphysis, the ends of the wire are brought out through the skin below the fat pad of the chin and about 3 cm. of the extruded wire is twisted and rolled upon itself to form a button in front of the chin a short distance from the skin surface. A rigid bar attached to a cranial fixation appliance is adjusted in front of the face between the forehead and the chin A horizontal extension attached to this bar rests in front of the upper incisors and is fastened to the upper dental arch bar Traction is effected by an elastic band which connects the wire button to the lower end of the bar The lower border of the body of the mandible is thus retained in position resisting downward and backward pull by the suprahyoid musculature.

When teeth are not available for anchorage of the retention appliance holes are drilled through the ends of the bone on each side of the osteotomy line and the fragments are wired together (Fig 932) the stainless steel wire is removed under local anesthesia after consolidation of the bones. A buried circumferential wire may be employed. A pull-out wire technique is also available the wires are twisted together the ends protruding intraorally through the mucosa After bony consolidation the wire is untwisted and removed under local anesthesia

A method to reinforce the fixation of the bone fragments by appliances which can withstand muscular pull without loosening follows a circumferential wire is passed around the mental symphysis and the ends of the wire are brought out through the mouth. The lingual end of the wire is passed between the teeth and the two ends of the wire are twisted together three or four times

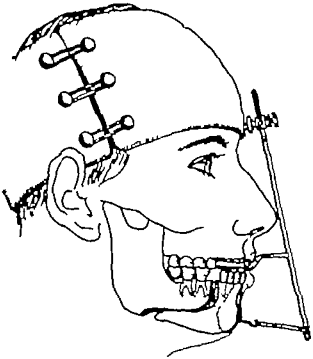

FIG 930 Extraoral splint consisting of a vertical bar extending from a plaster headgear to the level of the chin. A forked extension connects the bar to a band over the upper anterior teeth. A circumferential stainless steel wire (23 gauge) is passed around the symphysis the ends of the wire are brought out through the skin and twisted to form a loop. Traction is effected by elastic bands extending from the wire loop to the lower end of the vertical bar

in the oral vestibule One end of the wire is then threaded through the eye of a needle and looped over the nasal spine. The ends of the wires are twisted together again and tightened.

Patients with retrusion and atresia of the mandible, treated by elongation osteotomy and bone grafting, are shown in Figures 926 931 933 934 935 936 and 913

Case Histories

Figure 936 shows a condition which resulted from osteomyelitis of the mandible following extraction of a tooth at three years of age. The mandible was markedly retracted with the chin deviated to the left. The upper dental arch was normal. The lower dental arch was markedly distorted all the mandibular teeth were in excessive lingual occlusion. The anterior teeth were inclined toward the right side, with occlusal

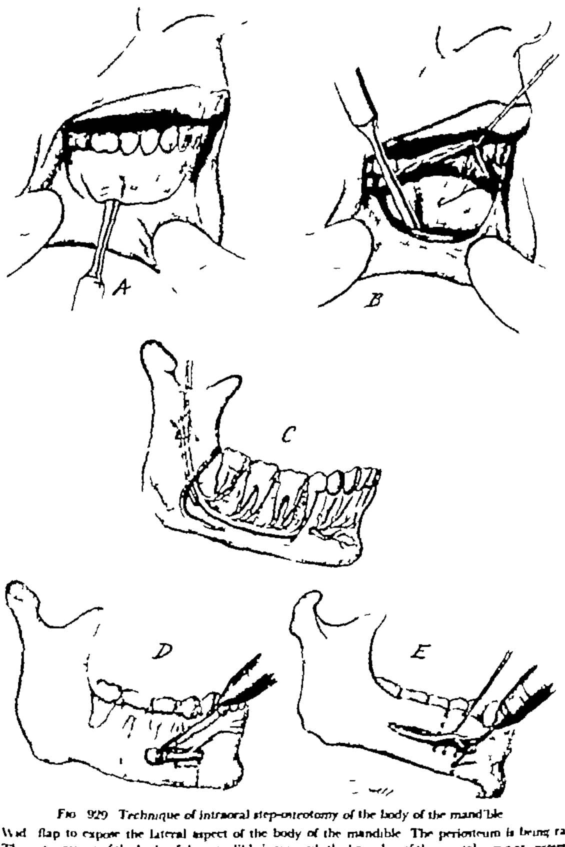

Fig. 929. Technique of intraoral step-osteotomy of the body of the mandible

A. Wide flap to expose the lateral aspect of the body of the mandible. The periosteum is being raised.

B. The outer aspect of the body of the mandible is exposed; the branches of the mental nerve are preserved.

C. Drawing representing the inferior alveolar nerve trunk, showing the mental nerve and the antero-inferior alveolar branch (shaded).

D. The inferior alveolar canal is uncovered by removing the outer plate, thus exposing the neurovascular bundle.

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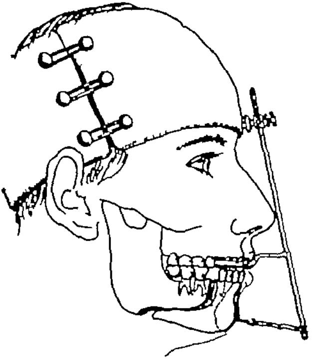

FIG 930. Extraoral splint consisting of a vertical bar extending from a plaster headgear to the level of the chin. A forked extension connects the bar to a band over the upper anterior teeth. A circumferential stainless steel wire (23 gauge) is passed around the symphysis the ends of the wire are brought out through the skin and twisted to form a loop. Traction is effected by elastic bands extending from the wire loop to the lower end of the vertical bar

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Patients with retrusion and atresia of the mandible, treated by elongation osteotomy and bone grafting, are shown in Figures 926 931 933 934 935 936 and 943

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Fig. 931

A and B Photograph showing retrusion of the mandible

C and D Photograph following correction of retrusion seen in A and B by bilateral osteotomy of the mandible

E, F and G Extraoral appliance retained for a period following surgery

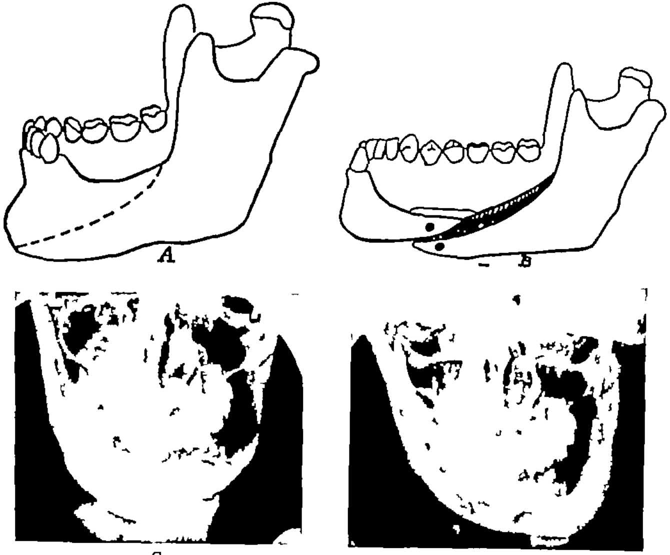


FIG 932

A and B. Diagrams illustrating oblique osteotomy of the mandible. The mandible is cut through diagonally with a dental burr after its lateral surface has been exposed intraorally A hole is drilled at each end of the bone segments and sutured together with stainless steel wire.

C and D Roentgenograms of case shown in Figure 935 before and after operation.

(From V H. Kazanjian, Am. J Surg 43:249 1939)

contact in the last molar region only On the left side, the posterior teeth were in occlusal contact to the cuspid region but were not suitable for fixation (Fig 937) Casts of the dentition were mounted on an articulator for study and a unilateral L-shaped sliding osteotomy was decided upon to correct the condition.

Intraoral appliances were constructed pre operatively The fragment on the right side was brought forward and to the right the sliding osteotomy was maintained in this position by interosseous wiring The fragment on the left was placed in proper occlusal relationship and maintained by inter maxillary fixation the fragment on the right was retained by intermaxillary wiring Satisfactory dental occlusion relationships were obtained (Fig 938)

A second operation was performed four weeks later for further contour restoration and also to strengthen the site of the previous osteotomy Iliac bone was transplanted to the site of the first osteotomy in order to strengthen this region and bone was added to the mandibular symphysis and along the

FIG 933

A and B Photograph of patient with unilateral retrusion of the mandible and deviation of the chin to the left.

C and D Postoperative photographs following elongation of the mandible in which a diagonal incision was made through the short side of the mandible (see Fig 932A)

E and F This procedure improved the dental occlusion as well as the facial contour

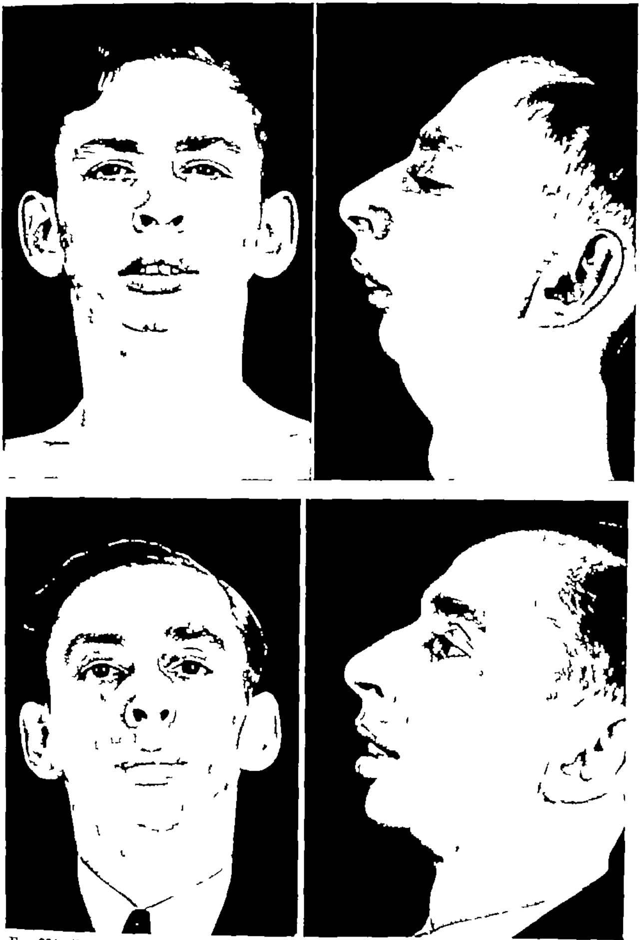


FIG 934 (*Upper*) Bilateral ankylosis of the temporomandibular joint present from childhood Condylectomy of both joints was performed at different intervals. (*Lower*) The symmetrical underdevelopment of the mandible was corrected by L-shaped osteotomy of both right and left sides of the mandible (see Fig 928C) The anterior section was brought forward and immobilized in its new position Result obtained following bone graft to the symphysis.

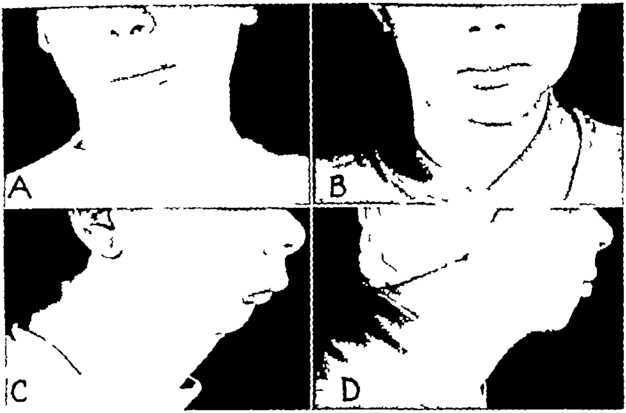


FIG 936

A. Unilateral mandibular retrusion with retrognathism caused by osteomyelitis in early childhood. The chin is deviated to the left, the left body of the mandible being shorter than the right.

B. Result obtained after step-osteotomy and bone grafting

C. Profile view of the patient.

D. Postoperative profile view

(Figs. 936 to 942 from V H Kazanjian, Plast. & Reconstruct. Surg 17:91 1956)

FIG 937 Casts of the dentition in patient shown in Figure 936 showing malocclusion the lower teeth are in lingual occlusion to the upper teeth.

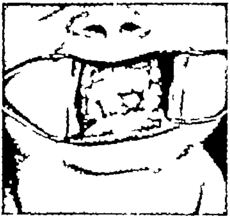


FIG 938. Photograph showing the occlusal relationships of the teeth after operation in patient shown in Figures 936 and 937

right side of the mandible to improve the external contour (Contour bone grafts are discussed later in this chapter)

A third operation was performed two weeks later to release adhesions of the lower lip to the alveolar process and to prepare the mouth for dentures. (The technique of the epithelial inlay is described in Chapter 25)

These three operative procedures resulted in an improved facial appearance, returning the chin almost to the median line, correcting the asymmetry of the face and replacing

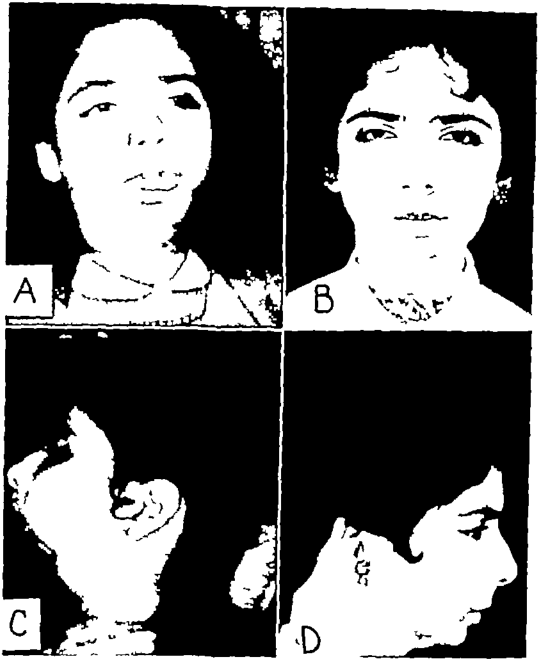


FIG. 939

A *Patient with mandibular atresia.*
B. Result obtained after osteotomy and bone grafting
C Profile view of patient
D Postoperative profile view of the patient

the alveolar processes in a position suitable for the construction of dentures (Fig 963*B D*)

Figure 939 shows another case of mandibular retrusion The lower third of the face was underdeveloped and retruded The chin was deviated to the left side with the typical flatness on the right side of the mandible commonly seen in patients with unilateral ankylosis of the temporomandibular joint Four anterior teeth in the upper jaw were missing The upper alveolar ridge was pressed against the lower jaw and the lower anterior teeth were missing The cusps of some of the posterior teeth were protruding through the alveolar ridges teeth were

missing and there was marked distortion of the alveolar arches of both jaws (Fig 940) The condition resembled bilateral ankylosis of the temporomandibular joints clinically but x ray examination revealed that only the right joint was involved. The ankylosis was released in a first procedure (see Chapter 26)

An elongation osteotomy was performed in a second operation and the bony fragments were maintained in apposition with interosseous wires in addition to the fixation appliance a circumferential wire was also placed around the symphysis in order to exert forward traction upon the anterior segment (Fig 941)

A third operation was performed three weeks later to bring the left side of the jaw still further forward the chin was not as yet in the median line. The wires uniting the surgically fractured site on the left side of the body of the mandible were removed and the bone exposed The fracture site was found to be healed but the left side was still too short. The opposing surfaces of the fractured bone were separated, the irregularities along the fracture site were smoothed out with rongeurs and the posterior extension of the anterior mandibular fragment was fractured and brought forward. The two ends of the bone were then butted and wired together thus achieving elongation of the left side and bringing the chin to the median line. The facial appearance was improved considerably

A fourth operation was peformed six weeks later to remove the interosseous wires and to add prominence to the chin by contour restoring iliac bone grafts. An epithelial inlay procedure was performed in a subsequent operation to prepare the alveolar processes for dentures (Fig 942A) A denture was then constructed which afforded the patient serviceable dental occlusion and added prominence to the chin (Figs. 939B D and 942).

Satisfactory elongation of the body of the mandible could not be obtained in this case without bone grafting

Bone grafting was also required to elongate the body of the mandible in a patient with bilateral temporomandibular ankylosis and marked underdevelopment of the mandible (Fig 943) This patient, despite the small size of the mandible (Fig 944) had a satisfactory complement of teeth to assure adequate fixation for band and arch bar appliances. The lower anterior teeth were inclined forward (Fig 945)

Preoperative cephalometric planning demonstrated that menton should be advanced for a distance of over 2 cm. (Fig 946)

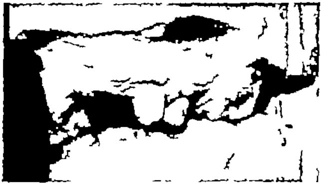


Fig 940 Casts of the teeth of the upper and lower jaws, prior to surgery showing extensive retrusion of the lower alveolar ridges.

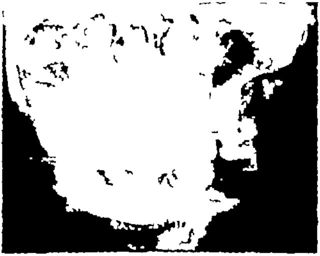
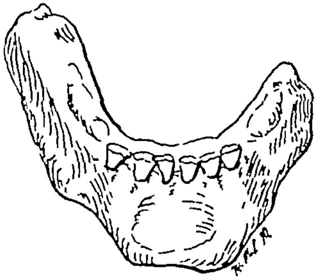


Fig 941 X-ray after reversed L-shaped osteotomy on each side of the mandible and the anterior portion was brought forward and held in position by circumferential wires and an extraoral traction appliance.

A



B

FIG 942

A. Photograph showing edentulous lower jaw in a forward position in relation to the upper teeth. The skin grafted area in the buccal groove allowed for construction of a denture with sufficient bulk to improve the facial contour

B. Drawing of denture constructed with buccal flange to increase retention and improve contour

and that the anterior segment of the body of the mandible could be advanced forward and upward permitting the teeth in this segment to assume satisfactory occlusal relationships with the teeth of the maxilla Because of the small size of the mandible maintenance of adequate contact between the bone fragments could not be assured and the interposition of bone grafts would be required to preserve the continuity of the mandibular arch For this reason we elected to perform an L-shaped line of osteotomy on each side of the mandibular body anterior to the mental foramen (see Fig 928C) This technique avoids interruption of the inferior alveolar neurovascular bundle and the mental nerve and preserves the sensory innervation to the lower lip and chin

In a preliminary operative procedure an kylosis was relieved by temporomandibular arthroplasty and interposition of facia lata

A bilateral L-shaped osteotomy was done through the intraoral approach and a circumferential stainless steel wire was looped around the mental symphysis, the ends being brought out through the skin below the fat pad of the chin and twisted into a button on the surface of the skin (Fig 911C) Traction on the wire loop permitted exerting forward and upward advancement of the anterior mandibular segment Iliac bone grafts were then wedged into the osteotomy areas to re establish the continuity of the bony arch An additional bone graft was placed over the mental symphysis through the intraoral approach to increase the forward projection of the chin this bone graft was placed under the circumferential wire Fixation was achieved by intermaxillary wiring to the band and arch bar appliances and a Barton bandage was applied

After consolidation of the bone grafts, an

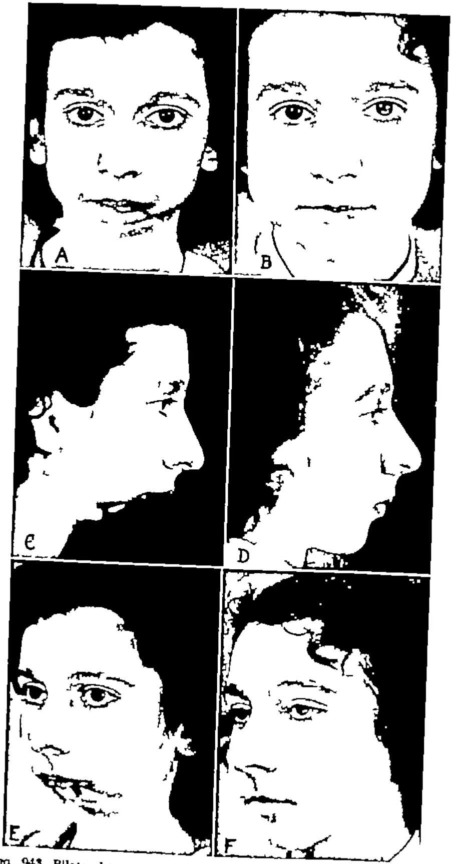
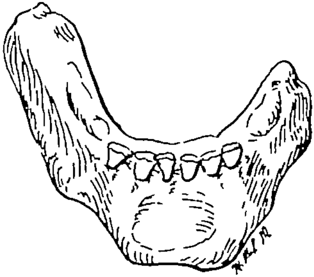


FIG. 943 Bilateral temporomandibular ankylosis and mandibular atresia
A, C and E. Preoperative views.
B D and F Postoperative appearance of the patient following
1 Temporomandibular arthroplasty
2. Elongation osteotomy of the body of the mandible.
3. Restoration of contour by iliac bone grafting through the intraoral approach.
(Figs. 943 to 946 from J M. Converse and H. H Shapiro, in publication)

A



B

Fig 942

A. Photograph showing edentulous lower jaw in a forward position in relation to the upper teeth. The skin grafted area in the buccal groove allowed for construction of a denture with sufficient bulk to improve the facial contour

B. Drawing of denture constructed with buccal flange to increase retention and improve contour

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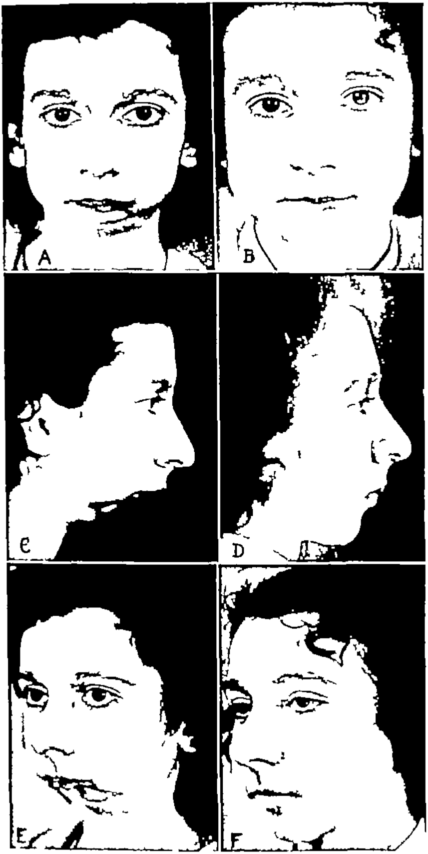

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A, C and E. Preoperative views.
B, D and F Postoperative appearance of the patient following:
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2. Elongation osteotomy of the body of the mandible.
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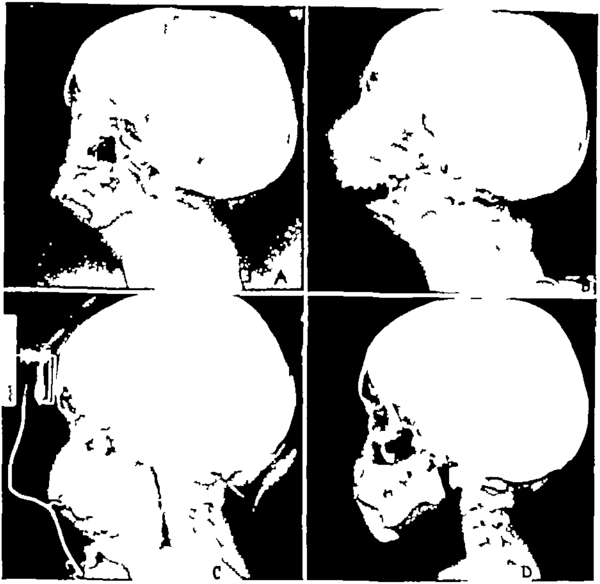


Fig. 944. Cephalograms of patient shown in Figure 943.

A. Preoperative lateral view cephalogram showing contour of bones and soft tissue.

B. Lateral view cephalogram showing opening of the mouth following temporomandibular arthroplasty.

C. Cephalogram showing external traction appliance and bone graft over the mandibular symphysis.

D. Final appearance after second contour-restoring bone graft.

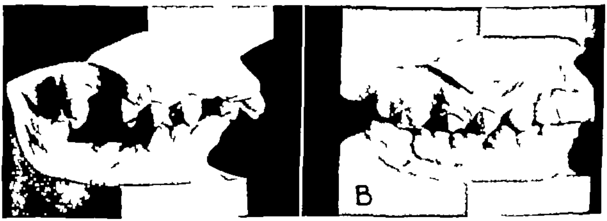


Fig. 945.

A. Preoperative casts of the dentition of patient shown in Figure 943.

B. Postoperative casts with improved dental occlusal relationships and prosthetic restorations.

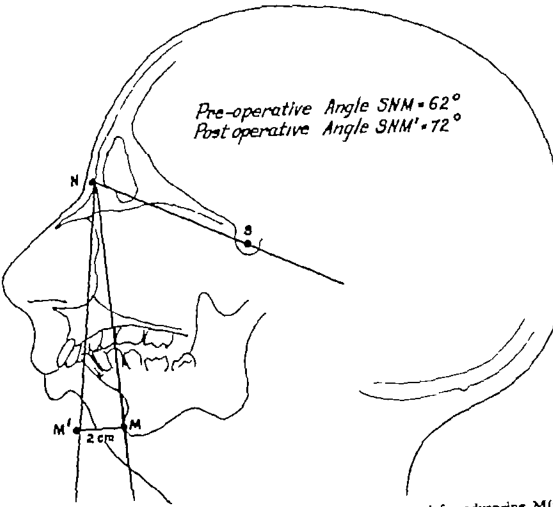


FIG 946. Tracing of cephalometric roentgenogram illustrating the need for advancing M(mentum) to M' a distance over 2 cm. (See planning of this case Fig 364 Chapter 14)

additional iliac bone graft was placed over the prior bone graft to the symphysis and anterior portion of the mandibular body and extended downward to increase the vertical dimension (Figs. 943 and 944*D*)

Contour Restoration by Bone Grafts

We have previously described the treatment of the atresic mandible by both unilateral and bilateral elongation osteotomy In most of these cases, in addition to elongation osteotomy it is necessary to further improve the facial contour by transplantation of bone to the body of the mandible. In mandibular atresia in edentulous patients, restoration of contour can be obtained by the epithelial inlay technique (see Chapter 25) deepening the buccal sulcus and thus making possible the insertion of a prosthesis to still further improve the facial contour (see Figs. 954 to 958)

In these varieties of mandibular deformities with an undeveloped symphysis, bone grafting is required to provide adequate contour

Two types of tissue are suitable for contour restoration of the symphysis autogenous cartilage grafts and bone grafts. Cartilage homografts and heterografts and prosthetic inserts are discussed in Chapter 19 Autogenous cartilage grafts survive and maintain their contour but do not consolidate with the underlying bone We prefer grafts of autogenous bone for we have found these to be uniformly successful Although the area of surface contact between onlay bone grafts and the mandibular bone is a wide one and is favorable to osteogenesis, homografts are not as reliable as autografts.

Bone grafts have been transplanted to the mandibular symphysis and to the anterior aspect of the body of the mandible either

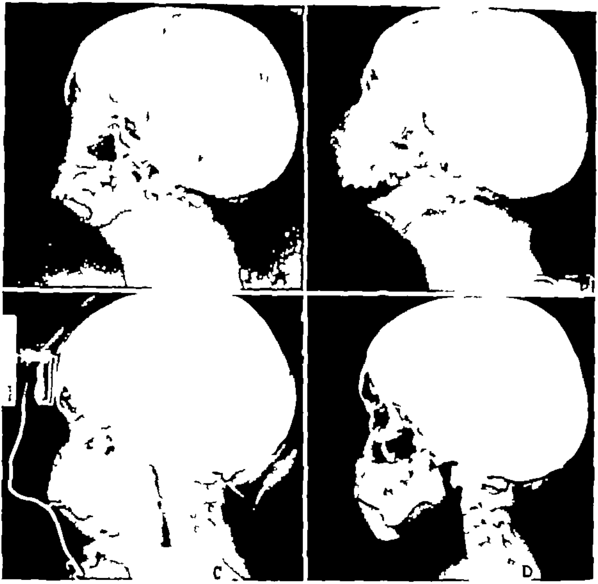


FIG 944 Cephalograms of patient shown in Figure 943

A Preoperative lateral view cephalogram showing contour of bones and soft tissue
B. Lateral view cephalogram showing opening of the mouth following temporomandibular arthroplasty
C. Cephalogram showing external traction appliance and bone graft over the mandibular symphysis
D Final appearance after second contour-restoring bone graft.

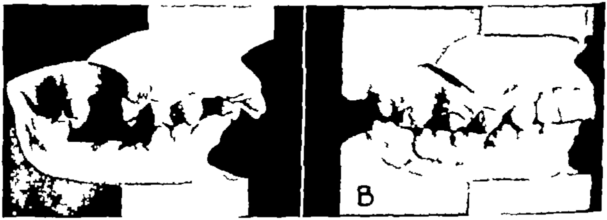
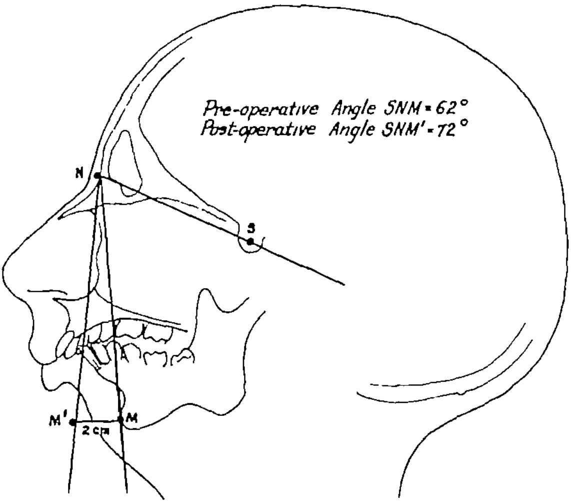


FIG 945

A. Preoperative casts of the dentition of patient shown in Figure 943
B. Postoperative casts with improved dental occlusal relationships and prosthetic restorations



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We have previously described the treatment of the atresic mandible by both unilateral and bilateral elongation osteotomy. In most of these cases in addition to elongation osteotomy it is necessary to further improve the facial contour by transplantation of bone to the body of the mandible. In mandibular atresia in edentulous patients, restoration of contour can be obtained by the epithelial inlay technique (see Chapter 25) deepening the buccal sulcus and thus making possible the insertion of a prosthesis to still further improve the facial contour (see Figs. 954 to 958)

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Bone grafts have been transplanted to the mandibular symphysis and to the anterior aspect of the body of the mandible either

through the external or the intraoral vestibular approach.

EXTRAORAL APPROACH (Kazanjian 1952) Prior to draping the face a vertical ink line is traced on the skin in the mid line of the chin the line serving as a guide when placing the transplant. An incision approximately 2.5 cm. in length is made within the submental fold (Fig 917C) The anterior surface of the mental symphysis is exposed subperiosteally and a thin layer of cortex is removed with an osteotome in order to produce a flat host bed for the graft (Fig 917C D) A triangular-shaped section of bone is removed from the crest of the ilium (Fig 917A B) shaped with the rongeur and file, and adapted to the anterior surface of the symphysis. Two holes are drilled through the bone near the upper border of the transplant (Fig 917B) a mattress suture is placed through these holes and the skin of the chin to retain the transplant (Fig 917E) Because the bone transplant is retained in position by the overlying soft tissues, the chin prominence may be further improved by adding thin slices of iliac bone either under or at the sides of the main graft (Fig 917F) The jaw is immobilized and pressure is applied with a Barton bandage padded with an adequate amount of gauze A postoperative liquid diet is prescribed Figure 918 shows a case of retrusion of the chin corrected by this technique Among these cases are those in which an excess amount of fat in the submental region accentuates the retrusion of the chin This excess fat can be removed during the contour restoration operation a procedure which is of great assistance in improving the postoperative contour

INTRAORAL VESTIBULAR APPROACH (Converse, 1950) In the intraoral exposure of the mental symphysis and the anterior portion of the body of the mandible, it is essential to make the initial incision in the mucosa

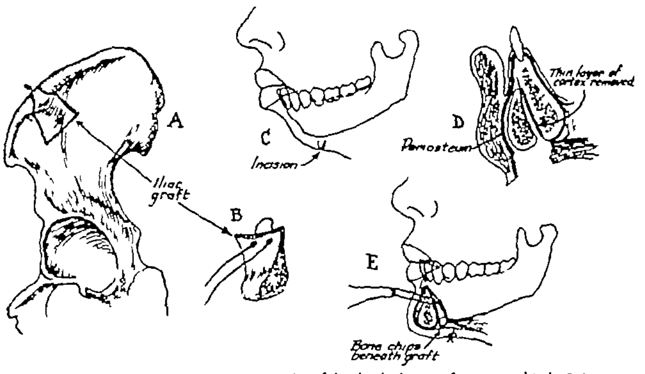

FIG 917 Technique of contour restoration of the chin by bone grafts extra-oral technique

A A triangular-shaped piece of bone is removed from the crest of the ilium

B. Two holes are drilled in the graft for the passage of guide sutures

C. An incision approximately 2 5 cm. in length is made in the submental fold.

D The bone graft is adapted to the anterior surface of the symphysis

E The guide sutures placed through the skin assist in retaining the transplant Triangular shaped wedges of bone may be placed beneath the graft to increase the projection

FIG 948

A. Patient with retrusion of the chin from childhood. A long period of orthodontic treatment maintained the teeth in fairly good occlusion but had no effect on development of the chin prominence. A previous operation in which preserved cartilage was used failed to correct the condition adequately

B. The addition of iliac bone to the symphysis and the resection of submental adipose tissue gave a satisfactory result.

(From V H Kazanjian, Am. J Surg., 83 635 1952)

above the vestibular fold for the vestibular cul-de-sac permits the accumulation of saliva and food debris which may interfere with the healing of the wound the incision is therefore established above the origin of the frenulum on the inner aspect of the lip (Fig 949*A*) Complications which result from this technique are due to exposure of the bone graft through the intraoral incision because of tension upon the mucosa of the lip and separation of the wound edges. The mucosa alone is incised and then from below the incision, is raised from the orbicularis oris muscle until the mucoperiosteum of the mandible is exposed (Fig 949*B*)

The flap of mucosa is retracted from the orbicularis as shown in Figure 949*C* and the periosteum is incised and raised with a small elevator the extent of the raised area depending upon the size of the graft.

If the elevation of the periosteum extends laterally the mental nerve and vessels should be avoided at their exit from the mental foramen Wide exposure extending downward to the lower border of the mental symphysis can be obtained by this route (Fig 949*D*) Bone grafts are then fitted over the symphysis (Fig 919*E* *F*) the grafts being placed over the mandibular cortex. If the chin requires additional forward projection, cancellous bone chips are placed between the graft and the body of the mandible to advance the graft (Fig 950)

The cortical surface of the graft is placed toward the host bone and the cancellous bone toward the skin surface because the cancellous surface of the graft can be carved and shaped more readily than the cortical surface. A number of cuts are made in the cortex of the graft with the tip of a bone-cutter or with the edge of a rasp The graft is then curved or partially fractured to attain the desired contour (Fig 952) a single graft or a number of grafts may be required.

A guide-suture assists in placing the bone graft into the correct position close to the lower border of the mandibular symphysis (Fig 950) The guide-suture is removed after the intraoral incision is sutured and the first strip of elastoplast is placed in the labiomental fold to prevent upward displacement of the graft. Catgut is employed for the guide suture for if the suture should break during its removal, the remainder of the catgut may remain buried subcutaneously Figure 953 shows a patient with microgenia corrected by intraoral bone grafting

The bone grafts are immobilized by elastoplast adhesive strapping (Fig 951) A 2 cm wide strip is placed in the labiomental

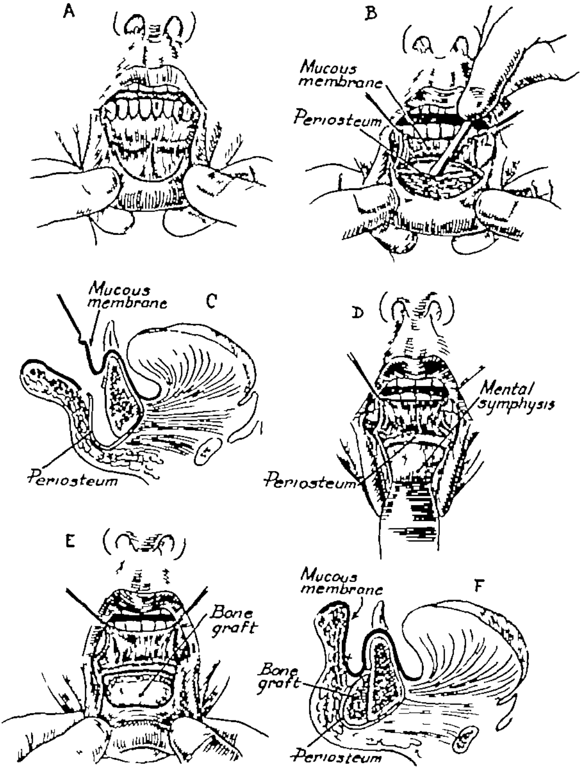

Fig 949 Intraoral approach to the mental symphysis

A Incision made in the mucosa of the lower lip above the frenulum. This type of incision is used for large implants for small implants a unilateral incision suffices

B The periosteum is incised and raised.

C Diagram showing the respective positions of the mucosal and periosteal incisions.

D Mental symphysis exposed.

E Position of the contour-restoring bone graft over the symphysis

F Bone graft in position

G Diagram showing the bone graft in position and the suture of the mucosal incision.

(From J M Converse Plast & Reconstruct Surg 6 295, 1950)

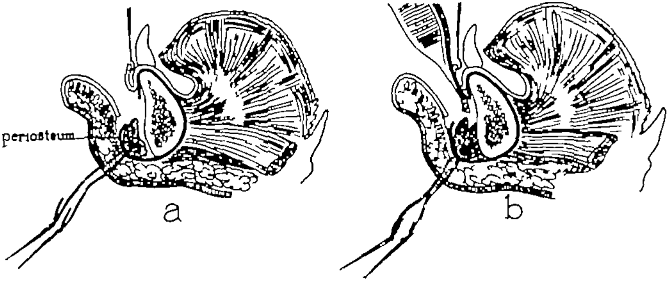

FIG 950. Use of traction sutures for the placing of bone grafts in the region of the symphysis via the intraoral approach.

A. The bone graft is held in correct position by guide-traction sutures placed through the soft tissues of the chin.

B. Bone chips are packed between the host bone and the bone graft in order to provide sufficient projection of the graft.

(From J M. Converse, Plast. & Reconstruct. Surg 14.332, 1954)

fold above the grafts a second strip is added along the lower border of the symphysis, supporting the grafts from below Additional strips of elastoplast are placed over the skin of the chin the dressing is reinforced with plain adhesive and is maintained for a period of from five to seven days. No further dressing is required, for the bone autografts adhere to the underlying mandibular bone within a short period of time. This adhesive strapping may be reinforced by a Barton bandage for two or three days postoperatively

The intraoral route permits wide exposure of the body of the mandible when the mucosal incision is extended posteriorly (see Fig 965) Although the use of the antibiotics makes bone grafting by the intraoral approach possible, it should be emphasized that aseptic techniques are important and should be meticulously observed.

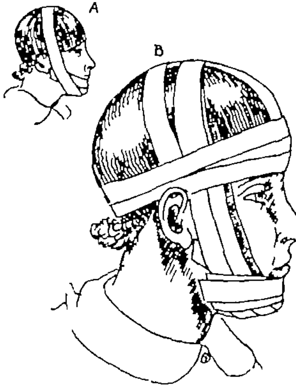

FIG 951 Technique of the pressure dressing for the fixation of the contour-restoring bone grafts.

A. Strips of elastoplast are placed in the labiomental fold and below the chin, thus limiting the upward or downward displacement of the bone grafts.

B. Additional strips of elastoplast are placed over the chin and are reinforced by strips of plain adhesive.

Contour Restoration by Bone Grafts and Prosthesis

Figure 954 illustrates a case in which osteotomy of an atresic edentulous mandible was deemed inadvisable Osteomyelitis had oc

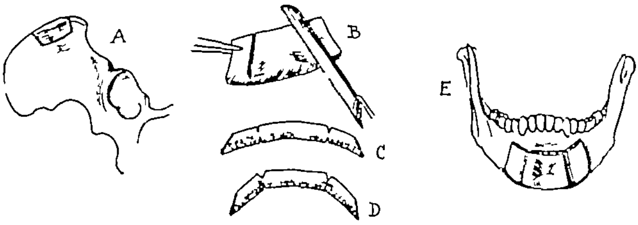

Fig. 952. Shaping the bone transplant

A Site of removal of bone graft from the inner aspect of the iliac crest.

B, C and D The graft is partly sectioned with a saw or the edge of a rasp to permit bending to a suitable curvature

E. Suitably-shaped graft adapted to the mandible.

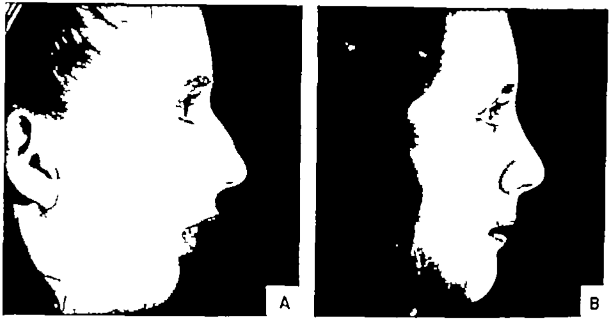

Fig 953

A. Microgenia with downward and backward slant of the lower lip.

B Improvement obtained by intraoral bone grafting over the mental symphysis and nasal plastic operation. (From J M Converse and R. M Campbell, Surg Clinics of No. America 34 375 1954)

curred following the removal of a tooth early in childhood and the mandible had failed to develop beyond the infantile stage. The condyles were undeveloped and the mandible articulated with the skull by way of the coronoid processes of the mandible (Fig 955) Because of the posterior position of the atresic mandible a base for a lower denture capable of articulating with the teeth of the maxilla could not be provided Sufficient bone was not available to permit an elongation osteotomy It was decided to add bone to the mandible anteriorly in order to provide adequate bony support for a denture and to obtain the final contour by deepening the anterior lower buccal sulcus with an epithelial inlay extended anteriorly to the bone graft (Fig 956) Two successive bone grafting operations were done through the external approach (Figs. 957 and 958) an epi

Fig 934 Contour restoration by bone grafting and prosthesis in mandibular atresia

A. Full face appearance of patient with mandibular atresia.

B. Restoration of contour obtained by bone grafting (in order to obtain a firm base for an epithelial inlay) restoration of a buccal sulcus by skin grafting and a denture with a flange extending downward and restoring chin contour

C. Preoperative profile view of the patient illustrating the bird-like profile.

D Postoperative profile view of the patient.

(Figs. 954 to 958 from J M. Converse and H H Shapiro, Am. J Surg., 88:858, 1954)

thelial inlay was employed in a later stage to establish a deep sulcus anterior to the bone grafts. The sulcus was extended down to the lower border of the newly bone grafted area.

Fig 955 *Sagittal plane cephalogram of patient shown in Figure 954* Note that the mandible articulates with the cranium by means of the coronoid processes

A temporary acrylic bite block was extended into the depth of the sulcus until the skin graft had healed the acrylic prosthesis was then modified by adding a flange which provided increased projection of the chin. A permanent acrylic prosthesis which consisted of a denture with a downward extension into the deep sulcus was made at a later date thus retaining the denture and also restoring contour to the lower portion of the face.

Another case is that of a native of Haiti with a severe facial deformity and temporomandibular ankylosis (Fig 959). An unsuccessful attempt to relieve the ankylosis had been made ten years previously The deformity affected the entire lower third of the face: *the patient presented the typical bird-like* appearance of temporomandibular ankylosis with atresia of the mandible The lips were thick and prominent The dentition was in poor condition a maxillary protrusion was due to the prominence of the maxillary dentition and alveolar processes. The anterior teeth of the lower jaw were inclined horizon

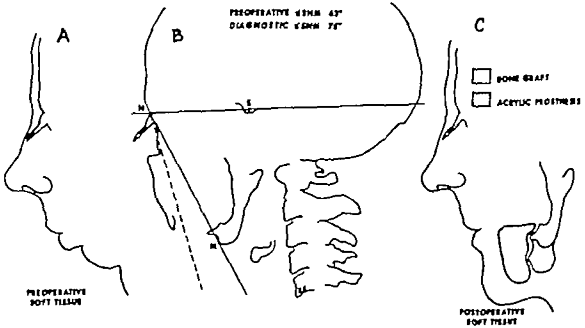

Fig 956. Sagittal plane tracings of the cephalogram in Fig 955

A. Tracing of the preoperative soft tissue profile

B. Tracing of the cephalogram in Figure 955 indicating preoperative diagnostic cephalographic planes and angles

C. Tracing of the postoperative sagittal plane cephalogram in Figure 958A The bone grafts and buccal prosthesis are indicated in the tracing

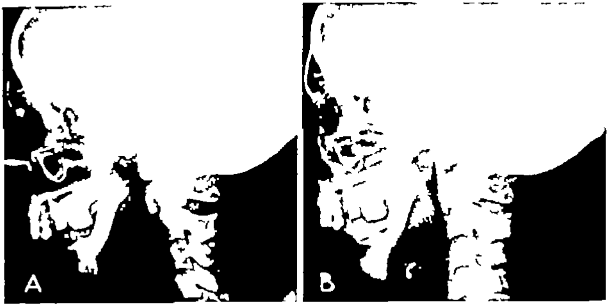

FIG 957 Later sagittal plane cephalograms of the patient shown in Figure 954
A. First postoperative stage showing bone graft.
B. Second postoperative stage showing additional bone graft.

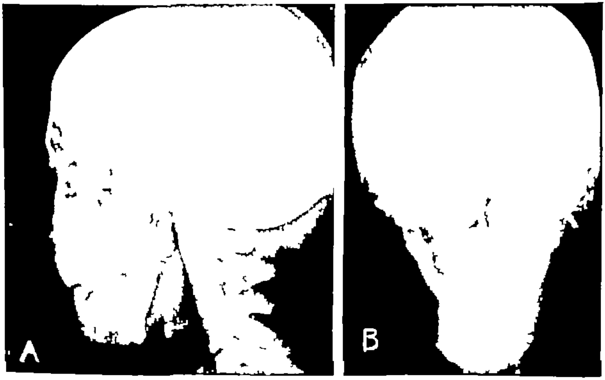

FIG 958. Postoperative sagittal plane cephalograms of the patient (Fig 954) A and B respectively sagittal plane and postero-anterior cephalograms of patient following establishment of a skin-grafted buccal sulcus and insertion of an acrylic buccal prosthesis.

Fig. 939 Mandibular atresia and temporomandibular ankylosis

A. Generalized underdevelopment of the mandible

B. Result obtained after two successive bone grafting operations, achieved through the intraoral approach, to restore mandibular contour

C. Atresia of the mandible and bird like profile

D. *Postoperative profile*

(Figs. 939 and 940 from J. M. Converse and H. H. Shapiro. Plast. & Reconstruct. Surg. 10:473, 19[illegible])

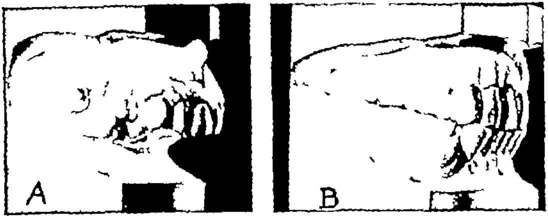

FIG 960. Plaster casts of the dentition of patient shown in Figure 959

A. Preoperative view

B. Postoperative view showing the prosthesis employed a complete denture for the maxilla and a fixed bridge extending from canine to canine, and a removable lingual bar appliance for the mandible.

tally (Fig 960*A*) the posterior teeth were embedded in the gingival tissues of the upper jaw X rays of the skull showed heavy bone formation in the right temporomandibular joint region.

Four stages of treatment were planned (1) relieving the ankylosis (2) removing infected teeth (3) restoring mandibular contour by bone grafts and (4) prosthetic restoration of the dentition

1 Thick bone binding the ramus to the skull was removed on the right side the atrophied condyle on the left side was resected. When the ankylosis failed to be relieved by these measures further exploration of the right ramus revealed bony union between the infratemporal surface of the maxilla and the medial aspect of the ramus. The jaws could be opened about 2 5 cm. following resection of this bone.

2. Four months later all of the lower teeth except the right and left canines were removed and an alveolectomy was performed.

3 Six weeks later bone was removed from the patient s right ilium and grafted through the intraoral approach subperiosteally over the symphysis and the lateral aspects of the jaw and beyond the mental foramen on each side.

Additional mandibular contour was necessary to further improve the patient s appearance The intraoral approach was again employed three months later

4 The maxillary incisor teeth were removed and the protruding alveolar process was resected A fixed bridge extending from cuspid to cuspid restored the lower anterior teeth A partial removable lower appliance and an upper denture were also made (Fig 960*B*) The patient s final appearance is shown in Figure 959*B* *D*

In this case because of the poor condition of the patient s dentition no attempt was made to advance the body of the mandible in order to improve the dental occlusion. It was decided to increase the contour of the underdeveloped mandible by a bone graft. Mandibular contour was restored by bone grafts introduced by the intraoral technique. The first bone graft was not sufficient to reestablish contour A second bone graft therefore was placed over the first a few months later Adequate occlusal relationships were established by prosthetic restorations (see also Figs. 1149 and 1150 Chapter 30)

Microgenia

In this type of malformation the chin is underdeveloped although the dental occlusion is good (Fig 953) In addition to microgenia, the patient experienced difficulty in closing the lips due to the attachment of the facial musculature to the inclined slope of the chin. Restoration of chin prominence by a bone graft restored contour and adequate lip function. In these cases the sub-

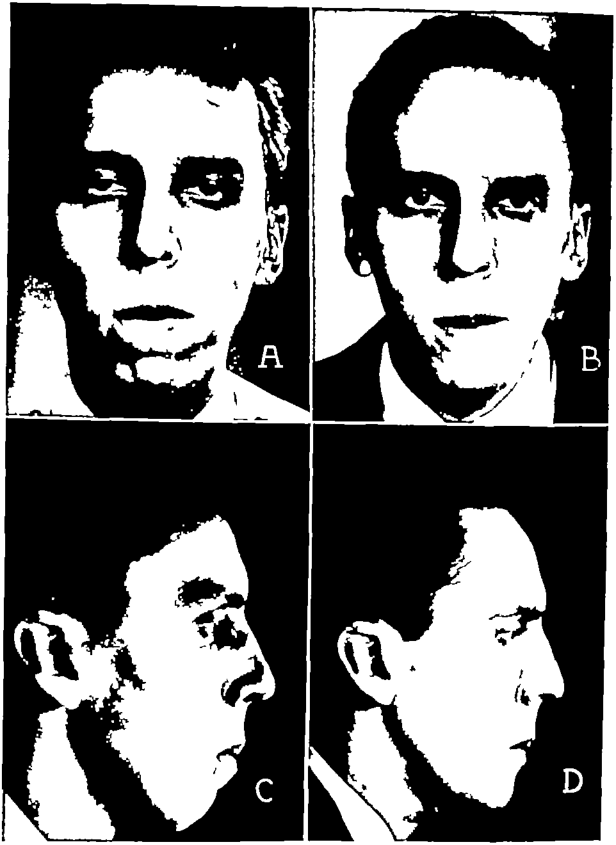

FIG. 9[illegible]

A Example of mandibular retrusion with microgenia. Note the forced contraction of the chin and lower lip to produce occlusion of the lips.

B Result obtained following bone grafting through the intraoral approach as illustrated in Figure [illegible].

C Preoperative profile view of the patient (see also Fig. [illegible]).

D Postoperative profile view of the patient.

(From J. M. Converse and H. H. Shapiro: Am. J. Surg. [illegible], 19[illegible].)

FIG 962. Sagittal plane cephalograms of an elongated and retruded mandible
A. Contour and thickness of the soft tissues.
B. View of the bony structure.

periosteal elevation of the facial musculature results in a release of tension thus improving function of the muscles of the chin and lip

Figures 961 and 962 show unusual varieties of mandibular malformation characterized by a short mandibular ramus with a wide goniac angle, increased height of the body of the mandible anteriorly and decreased height of the body posteriorly as shown in Figs 961 to 965 The normal bony protuberance of the chin is absent the anterior surface of the mandibular symphysis slopes downward and backward The vertical dimension of the lower third of the face is greatly increased.

Improvement of the appearance was obtained by grafting bone over the mental symphysis. Resection of a portion of the lower part of the body of the mandible was necessary to reduce the vertical dimension of the lower third of the face. The bone was resected from the lower portion of the body of the mandible and transplanted to the anterior surface of the body to increase the prominence of the symphysis (Figs. 964 to 966)

Mandibular Protrusion Prognathism

The term prognathism has been defined as a condition in which the lower jaw is oversized in relation to a normal sized maxilla and the teeth of the mandibular dental arch are in anterior relation to those of the maxilla (Fig 967)

Angle (1898) in discussing pronounced prognathism of the mandible condemned orthodontic interference stating that these cases should be avoided by the orthodontist, who should recognize the limitations of regular orthodontic treatment.

Case (1921) reported a few cases of prognathism which he had treated by judicious extraction of selected mandibular teeth followed by orthodontic treatment.

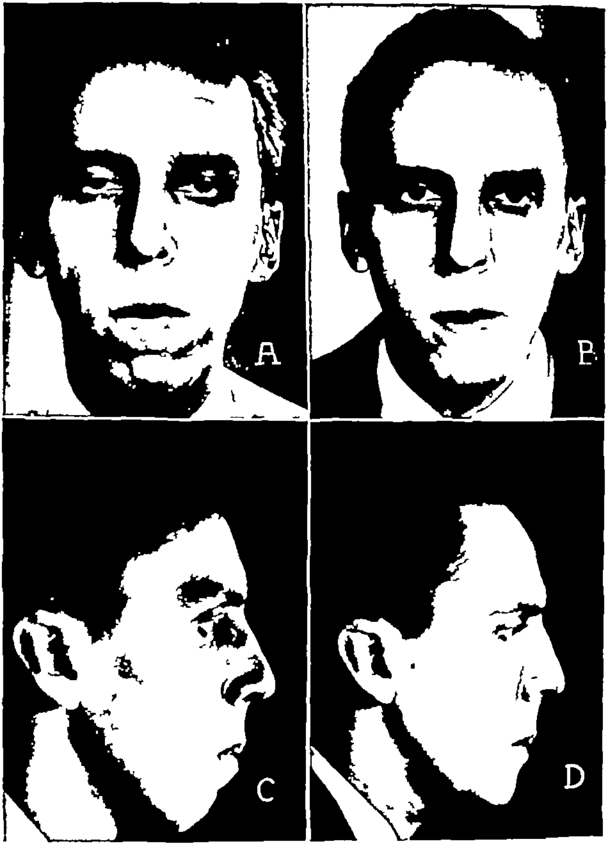

FIG. 9[illegible]1

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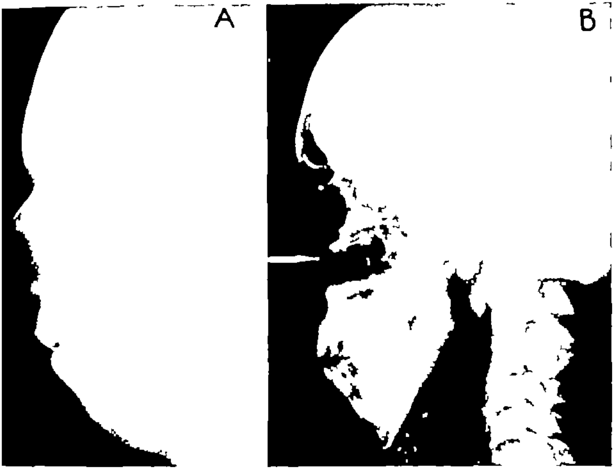
B. Result obtained following bone grafting through the intraoral approach as illustrated in Figure 9[illegible].

C. Preoperative profile view of the patient (see also Fig. 9[illegible]).

D. Postoperative profile view of the patient.

(From J. M. Converse and H. H. Shapiro, Am. J. Surg. 88:858, 1954.)



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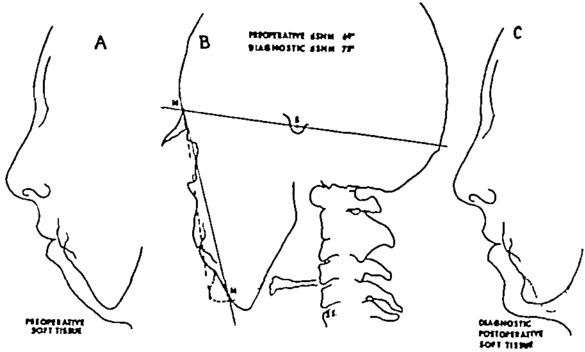


Fig 963

A. Tracing of the profile view of the soft tissues.

B. Cephalographic diagnostic planes and angles drawn on a tracing of the cephalogram.

C. Diagnostic postoperative soft tissue profile to be anticipated A bone graft removed from the lower border of the mandible and shifted to the anterior portion of the body of the mandible is planned.

(From H. H Shapiro and J M Converse Am. J Surg 88:864 1954)

Hullihen in 1849 performed an osteoplastic section of the anterior segment of the body of the mandible to correct a deformity due to scar contracture of the neck. It was not until 1898 that Blair performed the first successful operation for prognathism

Mandibular prognathism may be due to hereditary causes trauma or disease. Although the prevalence of prognathism in members of the same family in certain racial groups is cited in support of the hereditary factor in prognathism many such conditions have no family history Trauma and disease are responsible for some types of prognathism and open bite Such deformities in children due to severe burn contractures of the neck, are characterized by protrusion of the anterior portion of the body of the mandible. Patients with an extensive hemangioma which involves the lower half of the face and cheek and tongue often display marked prognathism this may be due either to the abnormally abundant blood supply to the excessive size of the tongue or to both of these factors. Malunion following fractures of the jaw may lead to abnormal occlusion of the teeth and open bite Acromegaly is a well known cause of prognathism acromegalics, however are rarely candidates for reconstructive surgery Underdevelopment of the maxilla in other cases of mandibular prognathism accentuates the mandibular deformity

Mandibular prognathism may be classified into four groups clinically based upon relative relationship of the mandible to the maxilla (1) A normal maxilla with a good dental arch but with an abnormally large mandible that results in prominence of the lower third of the face (2) Overdevelopment of the mandible combined with underdevelopment of the maxilla This condition is often seen in the postoperative cleft palate patient and usually shows considerable irregularity and crow ing of the maxillary

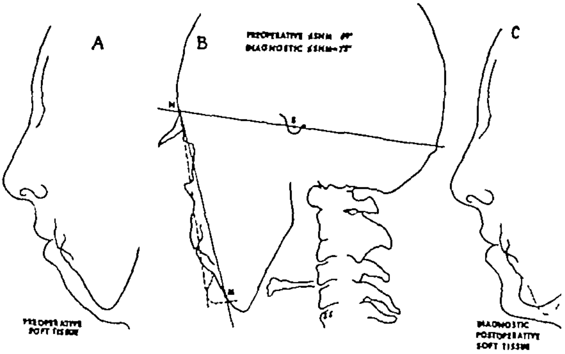
Fig 964

A. Mandibular retrusion with microgenia (see Fig 963) Note the repaired bilateral facial cleft.

B Result obtained following skeletonization of the mandible, resection of the lower portion of the mandibular body and transplantation of the bone over the anterior surface of the body (see Fig 966)

C. Preoperative profile view

D Postoperative profile view



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(From H. H. Shapiro, and J M. Converse Am. J Surg., 88:864 1954)

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Mandibular prognathism may be due to hereditary causes, trauma or disease Although the prevalence of prognathism in members of the same family in certain racial groups is cited in support of the hereditary factor in prognathism, many such conditions have no family history Trauma and disease are responsible for some types of prognathism and open bite. Such deformities in children due to severe burn contractures of the neck, are characterized by protrusion of the anterior portion of the body of the mandible Patients with an extensive hemangioma which involves the lower half of the face and cheek and tongue often display marked prognathism this may be due either to the abnormally dant blood supply to the excessive the tongue or to both of these factors union following fractures of the jaw lead to abnormal occlusion of the teet open-bite Acromegaly is a well known of prognathism acromegalics, howeve rarely candidates for reconstructive su Underdevelopment of the maxilla in cases of mandibular prognathism ac ates the mandibular deformity

Mandibular prognathism may be fied into four groups clinically based relative relationship of the mandible t maxilla (1) A normal maxilla with a dental arch but with an abnormally mandible that results in prominence lower third of the face (2) Overdev ment of the mandible combined with u development of the maxilla This con is often seen in the postoperative clef ate patient and usually shows conside irregularity and crowding of the max

FIG 964

A. Mandibular retrusion with microgenia (see Fig 963) Note the repaired bilateral facial cleft.

B. Result obtained following skeletonization of the mandible, resection of the lower portion of the mandibular body and transplantation of the bone over the anterior surface of the body (see Fig 966)

C. Preoperative profile view

D Postoperative profile view

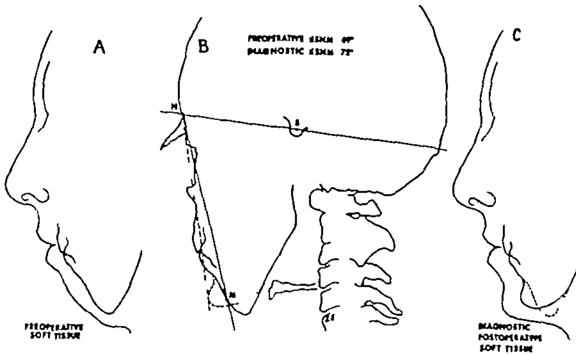

Fig 963

A. *Tracing of the profile view of the soft tissues.*

B. Cephalographic diagnostic planes and angles drawn on a tracing of the cephalogram.

C. Diagnostic postoperative soft tissue profile to be anticipated. A bone graft removed from the lower border of the mandible and shifted to the anterior portion of the body of the mandible is planned

(From H. H Shapiro and J M. Converse, Am. J Surg., 88:864 1954)

Hullihen in 1819 performed an osteoplastic section of the anterior segment of the body of the mandible to correct a deformity due to scar contracture of the neck. It was not until 1898 that Blair performed the first successful operation for prognathism

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Mandibular prognathism may be classified into four groups clinically based upon relative relationship of the mandible to the maxilla (1) A normal maxilla with a good dental arch but with an *abnormally* large mandible that results in prominence of the lower third of the face (2) Overdevelopment of the mandible combined with underdevelopment of the maxilla This condition is often seen in the postoperative cleft palate patient and usually shows considerable irregularity and crowding of the *maxillary*

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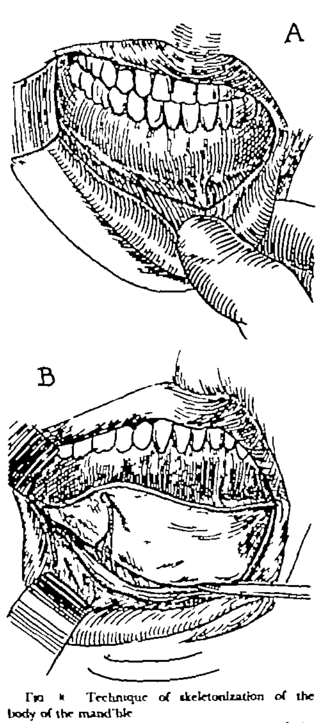


FIG. * Technique of skeletonization of the body of the mandible

A Incision made on the labial aspect of the buccal sulcus.

B Exposure of the body obtained by subperiosteal elevation of the soft tissues.

(from J M Converse & H H Shapiro in publication)

teeth and a high palatal vault the mandible appears to be normal in size but seems relatively prognathic in some of these cases because of atresia of the maxilla This type of deformity may be referred to as pseudo-prognathism. Cephalometric study aids in establishing the diagnosis. (3) The open bite is the outstanding feature in this group (4) A less frequent type of unilateral prognathism is due to hyperplasia of the head of the condyle. The lower jaw is pushed forward and to the opposite side as the condylar head increases in size. Hypertrophy of the entire half of the mandible also accompanies condylar hypertrophy The patient becomes aware of a gradual change in the occlusion of the teeth and of the contour of the face. This type of condition in our experience has always been unilateral.

Treatment of Prognathism

A mild degree of malocclusion due to the protrusion of the mandibular teeth usually responds to orthodontic treatment providing that the underlying cause is dental malocclusion and not overdevelopment of the body of the mandible· the condition becomes a surgical problem when the body of the mandible is overdeveloped

Two general types of operative procedures have been employed most frequently for the correction of mandibular prognathism One approach first employed in the United States by Blair (1915) is to remove a section of bone from each side of the body of the mandible the anterior segment is then set back into new occlusal relationships and immobilized The second method advanced by Babcock (1910) is to cut through the ramus on each side above the level of the inferior alveolar foramen recess the body of the mandible into the desired position and maintain fixation until consolidation occurs.

A number of variations of these two basic methods have been employed

PREOPERATIVE PLANNING. Preliminary planning is required to obtain accurate measurements of the size of the segment to be removed from the body of the mandible or the extent of posterior displacement of

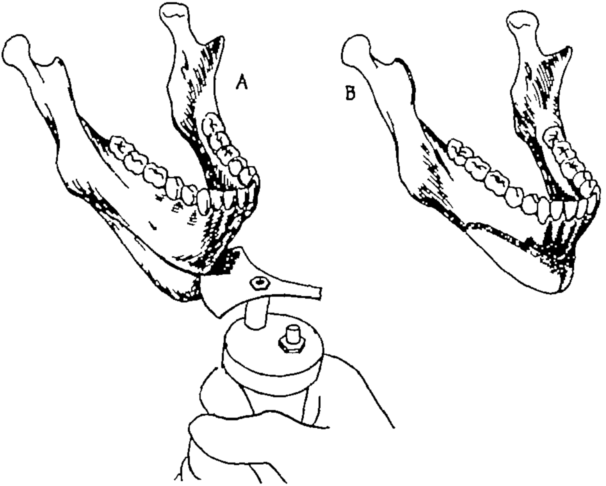


FIG 966. Resection and transplantation of bone from the lower portion of the body of the mandible
A. Resection of bone from the lower portion of the body of the mandible with a Stryker saw
B. The resected segment, split into halves, transplanted over the anterior portion of the body of the mandible.

the mandible after ramus section Study of the dental casts is necessary to obtain an improved postoperative occlusion. Casts of the upper and lower teeth are placed in occlusal relationships and mounted on an articulator A vertical line is drawn across the last molar teeth of maxilla and mandible (Fig 968) The upper cast is then placed into a more suitable dental relationship the vertical line on the upper teeth is extended downward to cross the lower teeth The measurement between the lines on the lower cast indicates the amount of bone to be removed from the lower jaw or the extent of backward displacement of the mandible after ramus section. The measurements should be made bilaterally for it is often necessary to remove more bone from one side than the other Planning prior to surgery is of prime importance and includes the study of cephalometric x rays, tracings (Fig 969) and cut-outs (see Fig 361 Chapter 14) Preoperative planning must include means of fixation of the separated fragments.

SECTIONING THE RAMUS OF THE MANDIBLE. Sectioning the ramus in favorable cases is advantageous because the dentition remains intact (Fig 970) The choice of the ramus or body section of the mandible is dependent upon the dental occlusion which exists before surgery and upon the best occlusion obtainable following the sectioning of the bone.

A description of the technique employed by Kazanjian since 1945 follows (Fig 970)

A curved incision from 2.5 to 5 cm is made through the skin just below the man

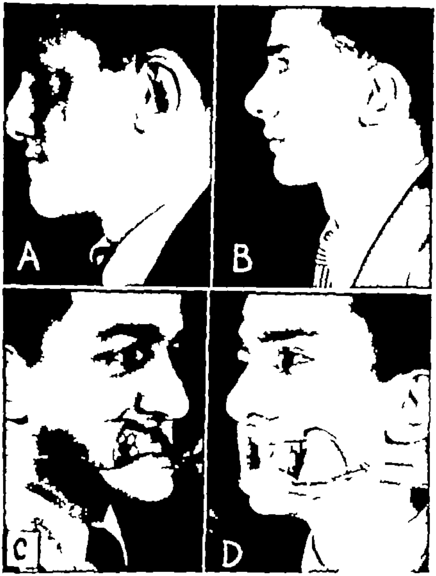


FIG 967 Correction of prognathism by ramus section

A and C An extreme type of prognathism with contact only at the last molar regions. Preoperative preparation consisted of applying cable arch wires. The ramus was cut transversely Bone was removed from the posterior edge of the ramus in order to prevent pressure against the facial nerve A similar procedure was then done on the opposite side The mandible was placed in correct occlusal relationship with the maxilla and maintained with elastic bands. Immobilization for approximately two months.

B and D Three years after the operation.

dibular angle Following the incision using a fine tipped hemostat, the subcutaneous tissues are separated by blunt dissection and the periosteum along the lower border of the mandible is exposed and widely incised the insertions of the masseter muscle are then elevated subperiosteally (Fig 970*A* *B*) The parotid gland and facial nerve branches are then elevated with the masseter muscle The soft tissues are raised and the lateral surface of the ramus is exposed by means of an angulated retractor (Fig 970*C*) Using a narrow osteotome under direct vision the ramus is cut on a bevel obliquely from below upward (Fig 970*D*) the line of section is established above the inferior alveolar foramen The level of the inferior alveolar foramen may be located on the face previous to osteotomy by measuring the distance between the head of the mandibular condyle and the mandibular angle the line of section is estab-

slightly over the half way mark of ertical dimension. One should remem at the mandibular ramus varies both gth and width the lateral view ceph m should also be studied for corrobo- previously to osteotomy At the level line of section a narrow tipped osteo- about 4 mm. in width is used, cut he bone from below in an oblique di n, thus establishing a beveled line of n. A similar procedure is performed e opposite side. This oblique section s in greater contact of the cut surfaces nting medial displacement of the up- agment by external pterygoid muscle and also avoids injury to the inferior ar nerve This open method makes le the completion of the operation direct vision and minimizes the dan- ccompanying troublesome bleeding e 971 shows the result obtained in the tion of prognathism by ramus section

EOTOMY WITH RESECTION OF A BONE NT TO SHORTEN THE BODY OF THE MAN Exposure of the body of the mandi obtained either by an external sub- ibular incision or by the intraoral ach.

is procedure is especially indicated in ulous or partially edentulous prog e patients because there is no necessity ie sacrifice of teeth in such cases it indicated in prognathism with open

eful preoperative planning is re d this includes (1) the measured nt of bone to be removed from either and (2) efficient means of fixation fol g surgery

lowing exposure of the inferior alveo- ndle, the anterior and posterior limits segment to be excised are marked on rtex of the mandible by a groove made the electrically driven burr

some cases the step-osteotomy tech shown in Figure 972 can be employed n others, the L-shaped osteotomy is ad geous, the horizontal arm of the L

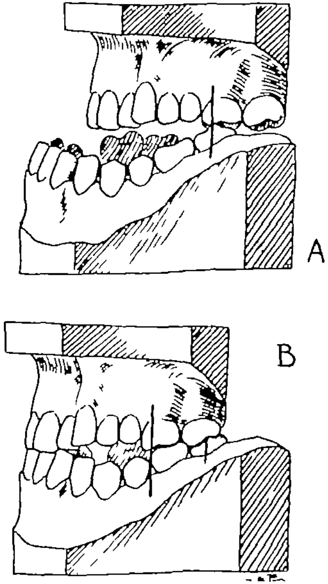


Fig 968 Plaster casts of the dentition as an aid in planning the prognathism operation.
(From V H Kazanjian, Am. J Surg 87-691 1954)

extending either toward the symphysis or toward the mandibular angle as shown in Figure 928 In the step osteotomy two segments are excised one posteriorly above the inferior alveolar canal and the other an teriorly below the canal (Fig 972) Crush ing or pinching the inferior alveolar nerve can be avoided by wide decompression of the canal the neurovascular bundle, drawn laterally is not compressed. Bony contact is maintained by fixation appliances in addi tion interosseous wiring is used, especially when an insufficient number of teeth are available for fixation.

The inferior alveolar nerve may be in

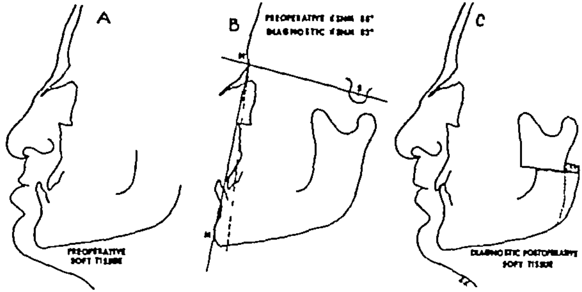


FIG 969 Tracings made from a cephalogram of a prognathic patient
A Tracing of the soft tissue profile
B Cephalographic diagnostic planes and angles drawn on a tracing of the bony structure
C. Diagnostic postoperative view the posterior extension of the ramus is indicated.

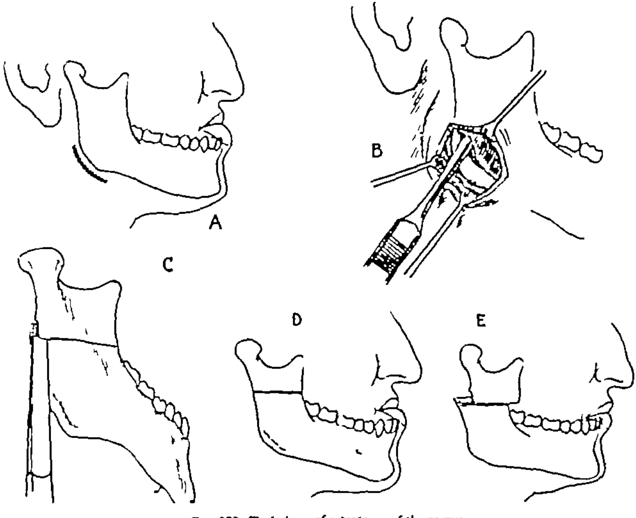


FIG 970. Technique of osteotomy of the ramus
A External incision made below the angle of the jaw
B The periosteum and masseter muscle are raised from the outer aspect of the ramus
C. Subperiosteal retraction, with retractor gives exposure for osteotomy
D The osteotome introduced from below cuts through the ramus obliquely
E and F Backward displacement of the mandible after osteotomy

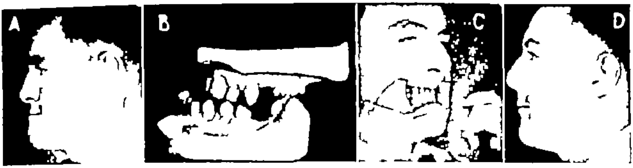


Fig 971 Correction of prognathism by ramus section

A. Appearance of prognathic patient prior to surgery

B. Preoperative occlusal relationships of the teeth of the maxilla and mandible.

C. Occlusal relationships obtained after ramus section.

D Postoperative appearance of the patient.

jured resulting in anesthesia of the lower lip if the technique of exposing the nerve as previously described is employed the effects of injury are temporary sensation gradually returns to the lip

CHOICE OF RAMUS OR BODY SECTION TECHNIQUE. The choice between ramus and body section technique is dictated by two principal considerations (1) correction of the deformity and (2) improvement of the dental occlusion

The advantages of cross sectioning the ramus are (1) it is probably a more simple operative procedure (2) there is no interference with the inferior alveolar nerve and (3) greater efficiency in mastication is obtained as no teeth are sacrificed The latter is the most important factor in favor of this approach Some of the objections to osteotomy through the ramus have been that the normal line of action of the powerful muscles of mastication is disrupted and that it is therefore not possible to push the mandible back to any great distance without completely changing the line of the pull and function of these muscles. Reexamination of prognathic patients operated upon through the ramus shows that the mandible can be pushed back as far as needed and changing the vertical direction of the muscles is not the cause of failure in this type of operation.

In certain extreme prognathisms the amount of posterior displacement may result in protrusion of the posterior border of the ramus impinging on the facial nerve. This hazard is obviated in such cases by resecting the protruding posterior border of the ramus

The body section technique is indicated in prognathism with open bite or in cases of prognathism with cross-bite and deviation of the jaw to one side. This technique permits placing the anterior section of the mandible in its proper occlusal relationships. Osteotomy through the body of the mandible offers the advantage of establishing a wide surface of contact between the bone fragments. An added advantage of the operation through the body is that of obtaining a more satisfactory appearing mandibular arch in the markedly prognathic and hypertrophied jaw as a result of reducing the size and modifying the curve of the dental arch

Disadvantages of osteotomy through the body of the mandible include the possibility of non union of injury to the inferior alveolar nerve, the sacrifice of teeth and possible postoperative infection

When properly planned the chances of inadequate bony contact and non-consolidation are slight. After a period of approximately eight to ten weeks, if there is no evidence of consolidation the area may be reinforced by a thin plate of transplanted bone If following osteotomy the area of contact seems inadequate to insure con

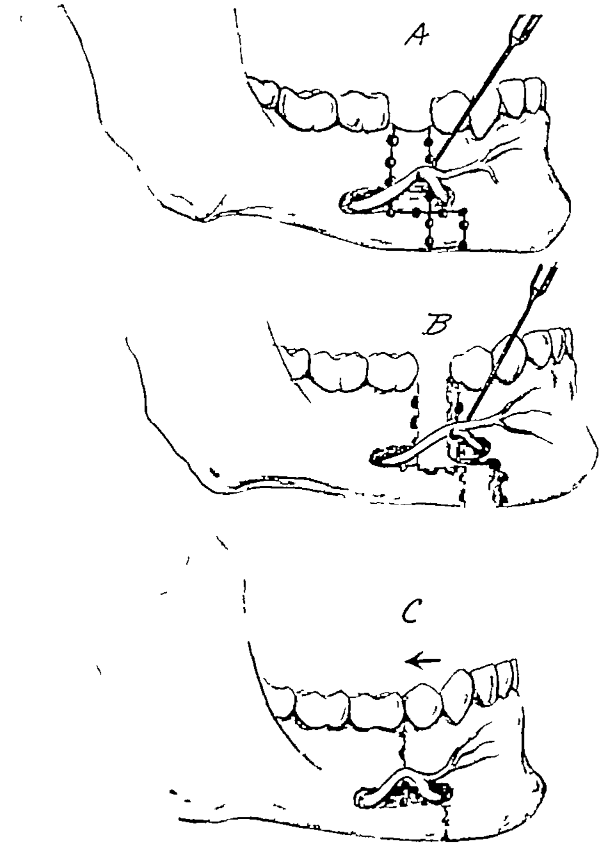


FIG. 972. Step-osteotomy with resection of a bone segment to shorten the body of the mandible.
A. The inferior alveolar canal and neurovascular bundle are exposed.
B. A segment of bone, determined preoperatively, is removed.
C. The anterior segment is moved posteriorly, achieving contact of the fragments. Pinching of the inferior alveolar nerve is avoided.
(FIGS. 972 and 973 from J. M. Converse and H. H. Shapiro, Plast. & Reconstruct. Surg. 10:473, 1952.)

solidation, chips of bone from the resected segments of the mandible can be added at the time. Injury to the inferior alveolar nerve should not occur if osteotomy is performed after the neurovascular bundle is exposed.

It is usually necessary to sacrifice teeth but the results achieved in the correction of the deformity justify the procedure. The continuity of the dental arch is re-established after a segment of the body of the mandible has been resected. Many prognathic patients have a defective dentition with gaps in the dental arch due to prior loss of teeth which are convenient sites for osteotomy and resection of bone.

Infection is minimized or eliminated by the removal of diseased teeth prior to operation and by instituting a pre- and postoperative program of oral hygiene.

OTHER TECHNIQUES FOR THE CORRECTION OF PROGNATHISM. A number of other techniques employed to correct prognathism include (1) resection of the condyle (Dufourmentel, 1921; Gonzalez Ulloa, 1951); (2) section of the neck of the condyle (Fig. 973). Resection of the head or section of the neck of the condyle disrupts temporomandibular joint function. (3) section of the ramus employing the Gigli saw (Kostecka, 1931) and section of the ramus with a saw through the retroauricular approach, techniques widely employed by Scandinavian surgeons (Hogeman, 1951) are procedures which we have not employed. (4) low ramus section below the foramen after decompression of the inferior alveolar canal is laborious because of the deep position of the inferior alveolar canal.

Because the techniques used and described by the authors have given satisfactory results in a wide variety of cases, they are advocated in preference to others.

Treatment of the Edentulous Prognathic Patient

In moderate prognathism the prosthodontist can usually provide the edentulous patient with efficient dentures to compensate for the faulty relationship of the alveolar processes. Surgical correction is required, however, when mandibular prognathism is marked (Figs. 974 and 978).

Resection of a segment of bone from each side of the body of the mandible is a relatively simple technique in the edentulous prognathic mandible. In the case shown in Figure 974*A* it was considered advisable to excise a section of bone about 1 cm. long from each side of the body of the mandible.

An incision over the alveolar crest of the mandible was extended from the canine to the second molar region. The mental foramen and outer surface of the body of the mandible were exposed freely. A series of drill holes were made through the full thickness of the mandible with a No. 5 dental burr. The cutting began over the alveolar crest about 1 cm. anterior to the level of the mental nerve and was extended downward and posteriorly below the level of the mandibular canal for a distance of about 2 cm. The mental nerve was decompressed and the final separation was accomplished with a fissure burr. A square section of alveolar bone measuring about 1 cm. was removed from the body of the mandible. The anterior segment was then recessed in its new position and joined to the posterior fragments by interosseous wires and a circumferential wire (Fig. 975). The incised mucosa was sutured with interrupted 4-0 catgut. The roentgenogram (Fig. 976) shows the postoperative result. Figure 974*B* shows the improvement of the facial appearance.

The advantages of the removal of a measured section of mandible anterior to the mental foramen are (1) the inferior alveolar nerve is not severed; (2) direct contact of the mandibular fragments results in safe and rapid consolidation of the bone, and (3) no additional splinting is required when the fragments are held in contact by wire sutures as well as circumferential wires. This operation is particularly indicated when shortening an atrophic mandible in an elderly patient. A practical consideration

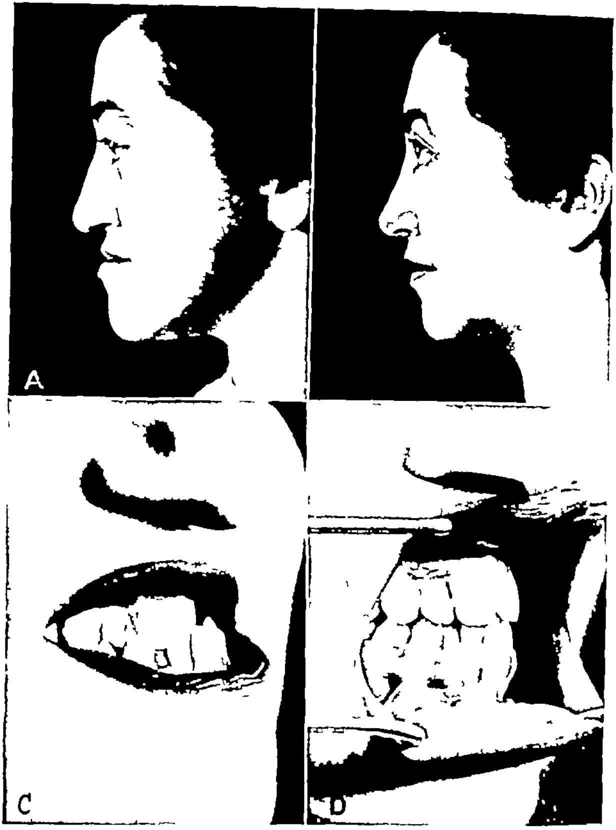


FIG. 9 3 Correction of prognathism by section through the neck of the condyle
A Mandibular prognathism in a female aged 19 years
B Result obtained by bilateral section through the neck of the condyle and nasal plastic operation
C View of teeth, showing mandibular prognathism with underbite
D Occlusion obtained after correction of prognathism

FIG 974

A. Edentulous patient with mandibular prognathism.

B. Result obtained after resection of bone from the body of the mandible as illustrated in Figure 975

to bear in mind when exposing the inferior alveolar nerve in an edentulous mandible prior to osteotomy is the superficial position of the mental foramen due to resorption of the alveolar process (Fig 977)

Figure 978 illustrates a case of mandibular prognathism in which the ramus was sectioned. The patient's teeth had been restored with artificial dentures a number of years previously Preliminary studies had shown that satisfactory jaw relationships could be obtained by recessing the entire body of the mandible which was done by the operation illustrated in Figure 970 New occlusal relationships of the upper and lower dentures were established and maintained by drilling through the dentures on each side and employing stainless steel wire to assure the coaptation of the dentures. A headgear with elastic traction immobilized the mandible until bony consolidation occurred (Fig 978*B*)

These two cases are illustrative of the eclectic approach in the treatment of the edentulous prognathic patient the type of operation most suitable for each case was selected.

Prognathism Associated with Open bite

Some prognathisms are associated with open bite. Resection of bone from the body of the mandible is a requirement for the correction of this type of deformity At tempts at osteotomy of the ramus in such cases have been discouraging there is a tendency for the bite to open postoperatively (Fig 979) Resection of a portion of the body of the mandible bilaterally obviates this difficulty

Adolescents with Prognathism

Young patients with prognathic tendencies show a rapid accentuation of mandibular protrusion and prognathism soon after the permanent teeth erupt the deformity becomes more marked as the facial bones particularly the mandible attain full development. Immediate improvement results if the deformity is repaired by osteotomy through the ramus before complete growth of the jaw the growth of the mandible however is not arrested and recurrence of the prognathism can be anticipated with further growth although to a lesser degree than before operation (Figs. 980 and 981) Osteotomy through the ramus should not be performed on patients under eighteen years of age. Children however with marked prognathism and inadequate masticatory mechanism should not be neglected. Of the two surgical approaches in such cases one should favor the removal of a measured section of bone from each side of the body of the mandible even though additional surgery may be required later

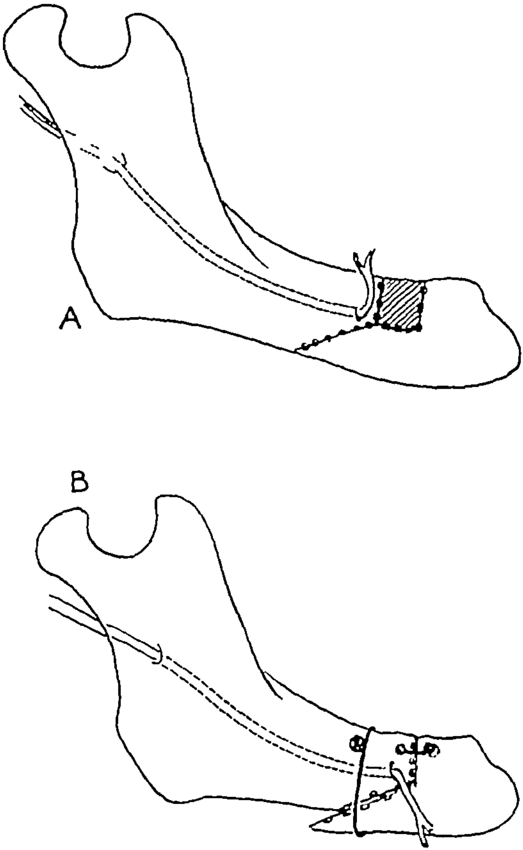


Fig. 97

A Resection of bone after reverse L-shaped osteotomy of the body of the mandible

B Circumferential wiring to immobilize the fragments

FIG 976. Roentgenogram showing circumferential wires for fixation of the bone fragments following the operation illustrated in Figure 974

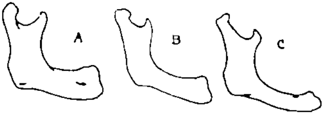


FIG 977 Diagram showing the progressive loss of height of the body of the mandible in the edentulous jaw

(After J C. B. Grant, *An Atlas of Anatomy* The Williams & Wilkins Co., Baltimore, 1954)

of surgical procedure can be better evaluated by discussing some of the complications which occur in both types of procedures.

INADEQUATE OCCLUSAL RELATIONSHIPS Minor imperfections in dental occlusion are not uncommon after immobilization has

FIG 978 Mandibular prognathism treated by ramus section

A. Mandibular prognathism in an edentulous patient.

B. Result obtained by ramus section as shown in Figure 970.

(From J M. Converse and H H. Shapiro. Plast. & Reconstruct. Surg., 10 473 1952)

Complications

The choice of operation can be determined only by careful preoperative study The relative merits of each general type been discontinued regardless of the type of procedure employed. Individual teeth are constantly subjected to the action of the opposing dentition and undergo slow mi

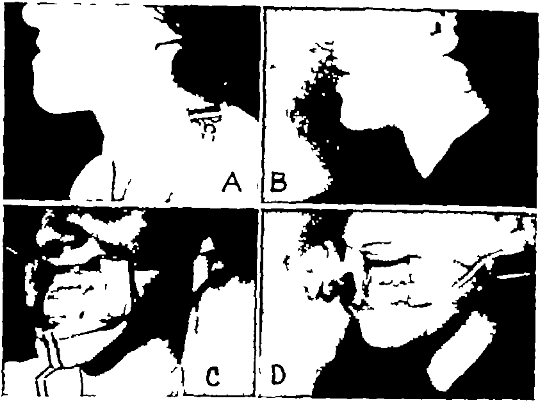


Fig. 979. Prognathism with open-bite.

A and C. This eighteen-year-old patient had severe mandibular prognathism with open-bite. Operation was performed which consisted of section of both ascending rami, pushing the lower jaw back and immobilizing it in the desired occlusion for three months. However, she gradually developed a slight open-bite after the intermaxillary wiring was discontinued, although not to the preoperative degree (B and D). This case and others like it demonstrate that the more successful approach is through the body of the mandible.

(Figs. 979 to 981. From V. H. Kazanjian, Am. J. Surg. 87:691, 1954.)

gration. This frequently results in improved occlusion, although it is often necessary to make minor adjustments, such as the judicious grinding of the cusps of teeth.

A more serious complication is the development of open bite or a gradual forward thrust of the lower jaw despite apparent consolidation of the bone. These conditions have occurred only in those patients in whom ramus section was performed, the pull of the muscles of mastication tending to cause displacement of the short upper fragment and the longer lower fragment.

As previously described, the short upper fragment tends to be displaced medially by the external pterygoid muscle and upward by the temporalis; the lower fragment is displaced upward and forward by the internal pterygoid and masseter muscles. Bony contact between the fragments may thus be lost, resulting in non-union. The body of the mandible is subjected to the action of the suprahyoid musculature; downward displacement may result in an open bite deformity. Neither non-consolidation of the ramus nor open-bite complications have occurred since employing the oblique osteotomy of the ramus described earlier in this chapter (Fig. 970).

NON-UNION. One of the more serious postoperative complications is non-union of the fragments, the principal causes being (1) inadequate bony contact of the separated parts, (2) infection, and (3) insufficient immobilization of the fragments.

1. Non-union of the surgically separated ascending ramus is a serious complication. We have examined cases in which the ramus had been sectioned close to the neck of

condyle rendering the upper fragment ontrollable Moreover the cut was made ight angles rather than along a beveled : and the cut ends of the bone lacked tact.

. Infection is more apt to be the cause of -union when the operation is performed ough the body of the mandible rather n through the ramus for in the former : the operative field is exposed to the l cavity and may result in contamination buccal fluids Adequate immobilization l the use of antibiotics however mini es this danger

Properly constructed fixation appli es are essential to maintain rigid im bilization of the fragments The frag nts must be impacted and the appliances uld be designed to maintain this close ptation We favor the band and arch : type of appliance. The appliances uld be strong enough to resist the post rative muscular pull to which they are jected.

perplasia of the Condyle and Body of ie Mandible. Unilateral Prognathism

Enlargement of the condylar process may ult from injury during childhood. Gruca l Meiseles (1926) Ivy (1927) Rushton 44) McNichol and Rogers (1946) Cernea 54) and others have reported cases of normal growth of the mandibular con e. The condyle usually assumes an elon ed shape, characteristic of this type of perplasia. The enlargement is progres- e the ramus of the jaw is elongated : body of the mandible is enlarged in all nensions and the occlusal relationships of : teeth are affected. Figure 982 illustrates deformity characteristic of hypertrophy the condyle

The left ramus of the mandible was longer in the right the mandible had shifted ward the right, with buccal occlusion of e teeth of the right side of the mandi : (Fig 983) Externally there was greater ominence of the left condylar region than

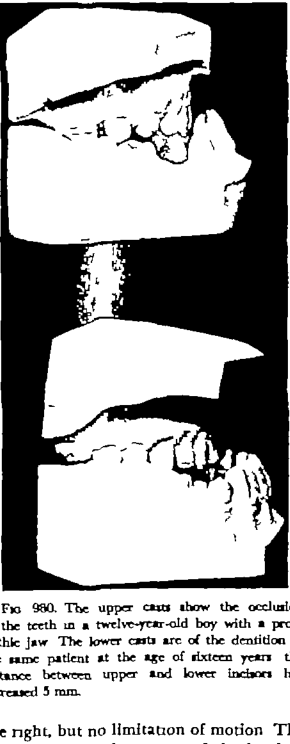


FIG 980. The upper casts show the occlusion of the teeth in a twelve-year-old boy with a prog nathic jaw The lower casts are of the dentition of the same patient at the age of sixteen years the distance between upper and lower incisors has increased 5 mm.

the right, but no limitation of motion The x-rays showed enlargement of the head of the left condyle (Fig 984) The lower jaw had been gradually pushed to the right side disorganizing the dental occlusion and con tributing to the asymmetry of the face.

An incision was made in front of the left ear the root of the zygoma was identified the bone was exposed the capsule of the joint was incised transversely and the joint cavity opened. Inspection revealed the head of the mandible to be enlarged to approxi

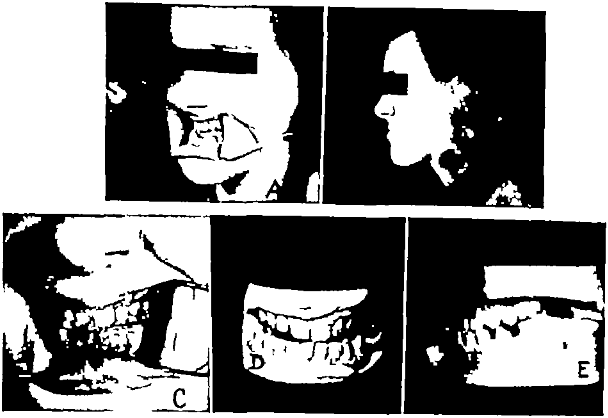


FIG. 981. At the age of thirteen years this patient showed a marked degree of prognathism (A and B). As she was a well-developed child, her age was somewhat overlooked at the time of operation. The operation was performed by section of both ascending rami and pushing back the lower jaw. The jaws were immobilized for two months postoperatively with good occlusion of the teeth (C). Pictures and casts of the teeth were taken nine months later (D). Note the gradual forward growth of the mandible. Although both the appearance and the occlusion of the teeth were improved by operation, the result was far from perfect. Osteotomy through the ramus should not be performed on patients under the age of seventeen years. Casts of the teeth taken approximately two years later showed the present dental occlusion.

FIG. 982. Hypertrophy of the left condyle. A, Note deviation of the chin to the right. B, Symmetry re-established after resection of the head of the condyle.

FIG. 983. Casts of the dentition showing shift of the mandibular dento-alveolar arch to the right caused by hypertrophy of left condyle.

mately twice its normal size. The condylar head and a portion of the neck of the condyle were removed. A strip of fascia lata 5 by 3 cm., was transplanted into the joint space and the wound was closed.

The dental occlusion was restored following the operation and the deviation of the mandible to the right was corrected (Fig. 982*B*).

Another patient illustrates hyperplasia not only of the condyle but of the entire half of the mandible. The history revealed an

FIG. 984 X-rays of the temporomandibular joints showing normal condyle (*right*) and hypertrophied condyle (*left*)

injury to the mandible following the removal of a tooth at the age of twelve years. The deformity affected the entire lower portion of the face (Fig 985) There was a marked hypertrophy of the entire right half of the mandible resulting in an elongation of the face on that side the chin was deviated to the left, and the angle of the mouth on the left side appeared elevated There was an extensive overbite of the upper anterior teeth over those of the lower accompanied by a lingual tilt of the mandibular teeth and the alveolar processes on the left side, when the teeth were in occlusion the incisal edges of the upper anterior teeth contacted the outer gingival tissues in the region of the lower incisors (Fig 986) The anterior teeth of the lower jaw inclined toward the right side.

Correction of the dental occlusion by surgical sectioning of the body of the mandible was planned in a first operation. Resection of a segment of the hypertrophied body of the mandible on the right side was decided upon as the next corrective procedure. Contour restoration of the mandible by bone grafts and a nasal plastic operation were final procedures. The splints and molar bands were cemented to the teeth previous to surgery the mandibular arch bar was to be inserted into the tubes and wired to the teeth and to the hooks on the maxillary splint following section of the mandible.

A step-osteotomy on each side in the region of the mental foramen was performed. To permit shifting the body of the bone to the left side, a segment of bone was removed in the area of the osteotomy on that side without severing the inferior alveolar nerves and vessels. The prepared arch bar was then placed into the buccal tubes the teeth wired to the arch and intermaxillary fixation assured.

Six weeks later while intermaxillary fixation was still maintained a submandibular incision was made on the left side exposing the body of the mandible. The incision was extended to the mandibular angle on the right side and the body and angle of the bone were exposed after reflecting the periosteum. A segment of the lower portion of the body and angle about 10 by 4 cm. in size, was outlined for resection the inferior alveolar nerve and vessels extended through the area to be resected the neurovascular bundle was exposed, lifted out of the bony canal and retracted (see Fig 987) The bony segment was resected and the inferior alveo-

Fig. 986. Hypertrophy of the right half of the mandible

A Preoperative view showing the asymmetry of the lower portion of the face and the deviation of the chin.

B Postoperative appearance of the patient.

C Preoperative appearance Note the large size of the mandible

D Postoperative appearance

(Figs 985 and 986 from J M Converse and H H Shapiro Plast. & Reconstruct. Surg 10:473, 1952)

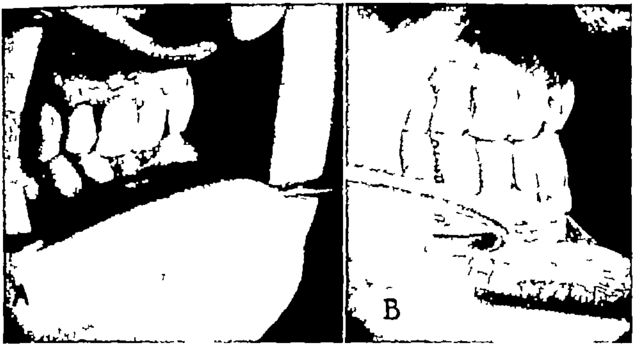


FIG 986. Preoperative (A) and postoperative (B) views of the dentition of patient shown in Figure 985

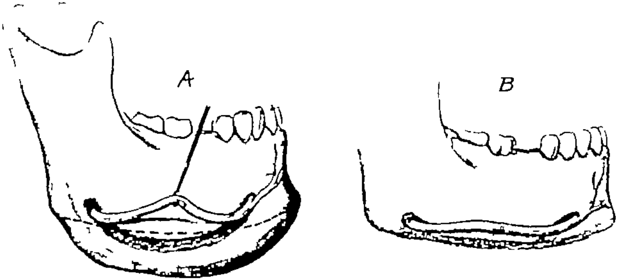


FIG 987 Transplantation of the inferior alveolar neurovascular bundle

A. Line of resection of hypertrophied bone (shown by broken line) The neurovascular bundle has been lifted from the canal in order to preserve it.

B Appearance of mandible following resection of hypertrophied bone.

lar nerve and vessels were transplanted to a higher level. The wound was then closed The symmetry of the mandible was improved as a result of this procedure The resected bony segment was stored in the bone bank.

Three months later the contour of the chin and the left side of the body of the mandible were improved by transplanting the stored bony segment previously resected and by trimming the lower border of the left side of the body of the mandible. One month later a nasal plastic operation was performed to correct the nasal deformity

This case illustrates the march of events in a mandibular malformation with malocclusion First, the malocclusion was corrected by bilateral osteotomy of the body of the mandible Second the contour of the mandible was restored by resecting hyper

FIG 985 Hypertrophy of the right half of the mandible

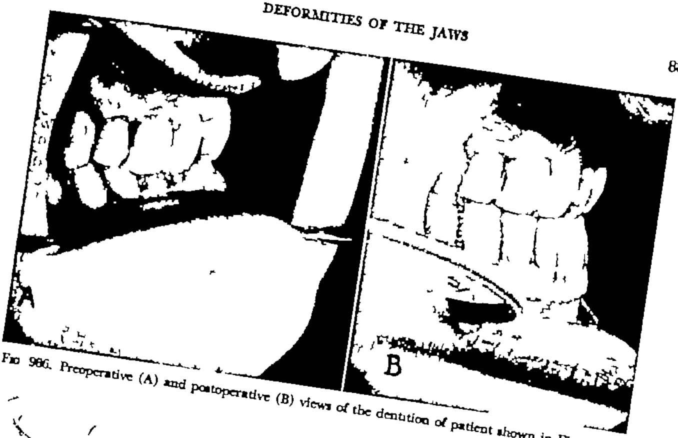
A. Preoperative view showing the asymmetry of the lower portion of the face and the deviation of the chin.

B. Postoperative appearance of the patient.

C. Preoperative appearance. Note the large size of the mandible.

D Postoperative appearance.

(Figs. 985 and 986 from J M. Converse and H. H. Shapiro, Plast. & Reconstruct. Surg., 10 473, 1952)



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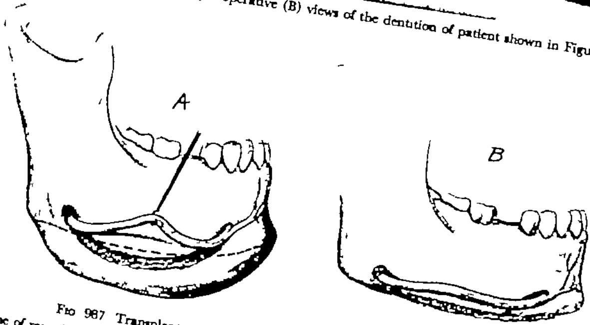

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trophic bone and transplanting bone where it was required. A nasal plastic operation further improved the facial contour (Fig 985)

When the patient was first examined x ray investigation of the right condyle failed to reveal sufficient hypertrophy warranting its removal Seven years later the patient complained of constantly increasing pain in the right condylar region, referred to the area of distribution of the auriculotemporal nerve. Surgical resection of a condyle which had become greatly hypertrophied over the seven year span relieved the patient of her symptoms. This case illustrates the necessity of resecting the condyle to arrest the hyperplastic process.

SURGICAL TREATMENT OF MALFORMATIONS OF THE MAXILLA

Maldevelopment of the maxilla, resulting from childhood injury may involve either the entire maxilla or one side only Because of the intimate relationship of the maxilla and the external nose, the latter structure is often affected, appearing flat or depressed the zygoma may also be flattened. Because the maxilla forms the medial portion of the orbital floor the rim of the orbital floor may be depressed backward, not only in the maxillary portion but also in the lateral or zygomatic portion The deformity may also involve the dentoalveolar segment of the maxilla resulting in malocclusion. The reestablishment of adequate dental occlusal relationships is an essential step in the restoration of facial contour Advancement of the maxilla may be indicated in exceptional cases of maldevelopment.

Maxillary retrusion accompanied by malocclusion occurs when both the dentoalveolar segment of the bone and the body are affected such types of cases may be classified under the term maxillary *retrognathism*

The treatment of maxillary malformations varies according to the type of deformity

Maxillary Retrusion

In some cases of maxillary trauma the entire maxilla and the dentition are retracted. In others the dental occlusion is not affected because the injury has affected the maxilla above the alveolar processes.

Dental prosthetic restoration can improve the contour when the alveolar processes alone are affected. Bone grafts are indicated for maxillary contour restoration (Fig 988) of deformed areas which involve the infra orbital zygomatic and nasomaxillary regions. An additional method which is indicated occasionally is the nasomaxillary inlay technique (see Fig 720 Chapter 22).

Surgical Advancement of the Maxilla

We have not attempted the surgical advancement of the entire maxilla for the correction of developmental maxillary atresia The procedure has been employed only in a recently malunited fracture of the maxilla by osteotomy through the partly consolidated fracture line Surgical advancement following osteotomy through the lower portion of the body and hard palate has resulted successfully (Fig 989) A description of such an operation follows in a case in which orthodontic treatment had failed. (Fig 990)

The operation was designed to advance the lower portion of the maxilla with the dentoalveolar component to re-establish dental occlusion and to restore facial contour It was necessary to sever the connections of the lower portion of the maxilla and also to separate the attachment of the nasal septum to the floor of the nose. The operation consisted therefore of both nasal and oral procedures the oral portion of the operation required surgery of both the oral vestibule and the hard palate

Under intratracheal anesthesia with the tube passing through the oropharyngeal airway the nasal mucoperichondrium was raised both sides and the septal framework were exposed. The anterior attachment of

FIG 988. Contour restoration of the maxilla by bone grafting

A. Example of multiple deformities of the face with retrusion of the maxilla due to underdevelopment.

B Restoration of contour obtained by bone grafts applied over the maxilla through the intraoral approach. In addition to orthodontic treatment a nasal plastic operation and an operation for the correction of lop ears were performed.

(From J M. Converse and H. H. Shapiro. Am. J Surg., 88:858 1954)

the cartilaginous septum and a portion of the vomer were severed from the floor of the nose (Fig 990D) The intratracheal tube was then removed from the oropharynx and reinserted through the nasopharyngeal air way thus permitting free access to the oral cavity

The first phase of the oral operation was initiated by a horizontal incision in the oral vestibule above the level of the tooth apices, reflecting the mucoperiosteum and exposing the pyriform aperture. The anterior wall of the maxilla was sectioned with a fine osteotome (Fig 990B), freeing the bone from the membranous sac lining the maxillary sinus. The sectioning was continued posteriorly on both sides, beyond and around the maxillary tuberosities (Fig 990C)

In the second phase of the oral operation the mucoperiosteum was reflected from the hard palate after an incision which followed the gingival contour The entire hard palate was exposed the anterior palatine nerves and vessels being preserved in the mucoperiosteum The horizontal line of section through the outer aspect of the maxillary tuberosity was then continued through both sides of the hard palate at a point anterior to the horizontal plate of the palate bone (Fig 990C) The palatine process of the max illa was sectioned transversely thus leaving intact the attachment of the greater portion of the vomer to the floor of the nose. This portion of the maxilla was then entirely freed (Fig 990E) A number of sutures were placed to reapply the mucoperiosteal flap to

FIG 989

A. Developmental malformation of the maxilla with retrusion of the middle third of the face.
B. Result obtained by surgical advancement of the maxilla and bone graft to the nose.
C. Preoperative view of occlusal relationships of the teeth.
D. Improvement in occlusal relationships following advancement of the maxilla.
(Figs. 989 to 991 from J. M. Converse and H. H. Shapiro Plast. & Reconstruct. Surg., 10:473 1952)

the gingival tissues. Closure was possible although some tension resulted from the anterior extension of the flap. The edges of the vestibular mucoperiosteal incision were sutured. The maxilla was then advanced to correct dental relationships (Fig 990F) and maintained by intermaxillary wiring to the buccal arch bar appliances previously attached to the teeth of the maxilla and mandible. The final phase of the operation consisted of applying cranial fixation (Fig 991) and removing the intratracheal tube Anti

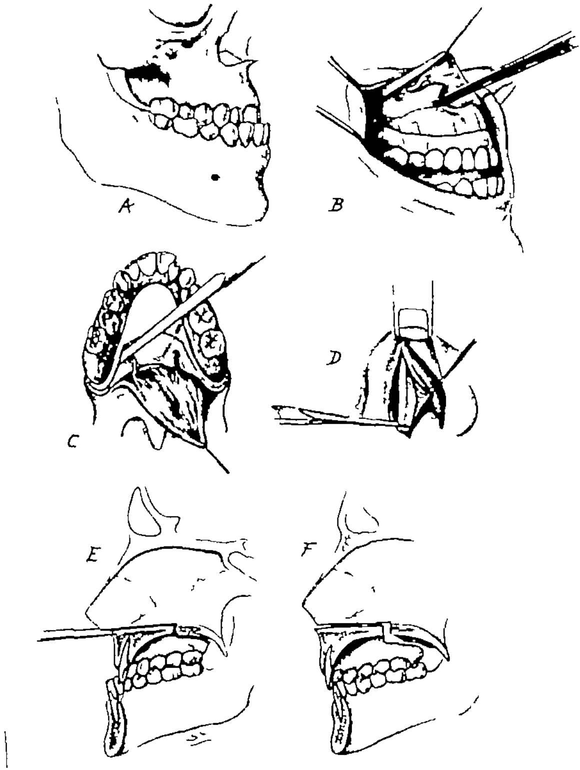


FIG 990. Technique for surgical advancement of the maxilla

A. Drawing of preoperative view of maldeveloped maxilla and malocclusion of teeth.
B. Line of osteotomy extending from pyriform aperture to the maxillary tuberosity on each side.
C. Line of osteotomy through the hard palate.
D Osteotomy through the septum at the level of the floor of the nose.
E. Mid-sagittal view showing horizontal section along the floor of the nose and transverse section through the hard palate.
F Advancement of the maxilla and re-establishment of dental occlusion.

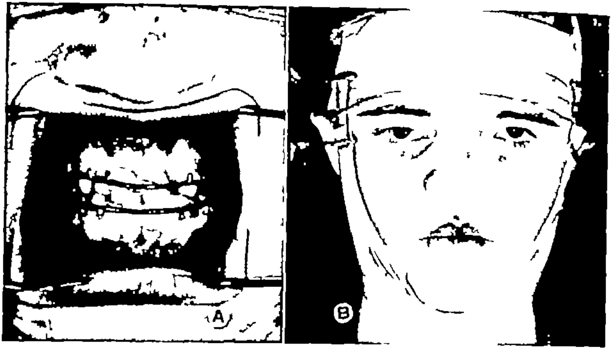


Fig 991

A. Appliances designed to insure intermaxillary fixation following osteotomy of the maxilla.

B. Simple type of traction apparatus to insure cranial fixation of the maxilla following osteotomy Two layers of adhesive tape are used the elastic bands assure upward traction over the safety-pins.

biotic therapy was initiated. Consolidation of the maxilla was well advanced at the end of five weeks in order to insure stability cranial fixation was maintained for an additional two weeks.

A nasal bone graft was done in a later stage. The appearance of the patient at the termination of treatment is shown in Figure 989*B* The improvement in the dental occlusion is shown in Figure 989*D*

Maxillary Atresia

Contour Restoration by Bone Grafts

Restoration of contour is achieved in such cases by bone grafts applied either through the intraoral or extraoral route.

THE INTRAORAL APPROACH In nasomaxillary deformities with depression not only of the nose but also of the adjacent maxillary portion of the face, bone grafts are placed into the nose (see Figs. 710 712 and 713 Chapter 22) and also over the maxilla around the edge of the pyriform aperture the exposure being established subperiosteally through the intraoral approach Crescent-shaped pyramidal pieces of cancellous bone and additional bone chips are placed on each side to correct the nasomaxillary depression (Fig 992)

The defects are repaired by a bone graft which consists of a suitably shaped shell-like segment from the medial aspect of the ilium employed as a bridge over the defect. Small fragments of cancellous bone are packed in the intervening crevices beneath this onlay of bone to further improve the bony contour The vestibular incision is sutured with 4-0 plain catgut sutures an external pressure dressing immobilizes the grafts.

The eyelids are sutured to avoid corneal abrasion should the lids be opened under the pressure dressing Fixation of the grafts occurs within one week and further dressings are not necessary Adequate restoration of contour has been obtained by this method (Fig 988)

THE EXTERNAL APPROACH In some cases of maxillary retrusion involving the infraorbital or anterior zygomatic area an external approach is advantageous the technique is

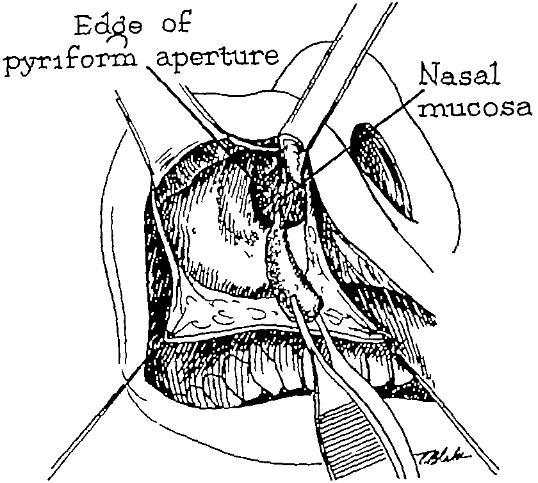


FIG 992. Type of exposure that can be obtained through the intraoral approach for the placing of bone grafts in the nasomaxillary area. The border of the pyriform aperture and the infraorbital neurovascular bundle are exposed.

described in Chapter 21 (see Figures 610 and 611)

MALUNITED FRACTURES OF THE JAWS

Some of the events leading to malunion of fractured bones include those in which the treatment of a jaw fracture has been neglected due to the general condition of the patient which has been too serious to permit effective treatment or when the extent of the damage in multiple comminuted fractures is such that reduction and fixation of all of the bone fragments is not possible or when loss of bone has occurred and the ends of the fragments close the gaps, thus disturbing the dental occlusion.

One should differentiate between deformities due to loss of bone and those caused by rotation overriding, and upward or downward displacement of fragments. Careful study of the facial contour employing photographs, and casts of the dentition which are mounted on a mechanical articulator assist in establishing a diagnosis and a plan for correction. The diagnosis is not obvious in some cases following malunited fractures of both maxilla and mandible, difficulty may be encountered in determining whether the upper or the lower jaw is in correct anatomical position Cephalometric roentgenograms are of assistance in establishing the diagnosis in such cases. Malunited fractures result in varying degrees of deformity and malocclusion of the dentition depending upon the extent of displacement of the fragments.

Deformity in malunited fractures may vary from marked retrusion of the maxilla, the chin and mandibular regions, to slight flatness or deviation of both maxilla and mandible.

Disturbances in the dental relationships are also variable Complete loss of occlusal contact with open-bite occurs in malunited impacted complete transverse fractures of the maxilla lack of occlusal contact also occurs after loss of bone in the region of the mental symphysis and consolidation of the remaining portions of the mandible Disturbances in dental occlusion due to slight backward displacement of the maxilla, or lingual rotation of a mandibular fragment are frequent occurrences

Treatment of Malunited Fractures

The decision to perform a secondary osteotomy in order to replace the malunited bone or fragment in a more satisfactory anatomical relationship depends largely upon the state of the patient's dentition When a normal complement of healthy teeth is present, the treatment should be directed toward the restoration of dental occlusion and masticatory function osteotomy is indicated in these cases. If the malocclusion is slight, dental operative procedures alone may suffice to improve the occlusion these include judicious grinding of cusps, re-establishing the occlusal plane or extraction of teeth when indicated Minor types of malocclusion often become adjusted without treatment the cusps of the teeth gradually assume new occlusal relationships.

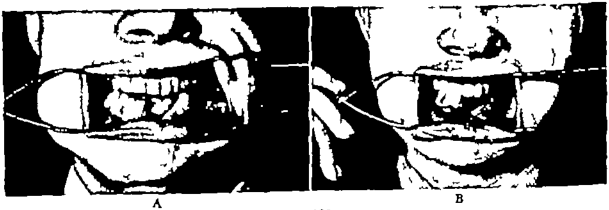
When the patient is edentulous or when a number of teeth have been fractured or avulsed at the time of injury adequate alveolar relationships can be established by means of contour bone grafts placed over the mandible or maxilla. A combination of methods of treatment may be necessary osteotomy prosthesis, and bone grafting to prepare the oral structures for dental restorations.

MALUNITED FRACTURES OF THE MANDIBLE. Malunion of mandibular fractures results from overriding, upward or downward displacement of fragments or loss of bone between the ends of the fragments (Figs. 993 994 and 995)

One of the methods previously mentioned, osteotomy prosthetics bone grafting, or a combination of these is selected as the treatment of choice

When osteotomy is indicated in malunited mandibular fractures, the prime considerations are the re-establishment of dental occlusion and facial contour In some cases, the jaw is refractured at the site of malunion in others, it may be advantageous to employ a more distant approach. A study of the dental casts is essential to determine the site of refracture

MALUNITED FRACTURES OF THE MAXILLA. The treatment of malunited maxillary fractures, as previously mentioned, varies according to the extent of the malposition and the state of the patient's dentition When the dentition is in good condition, but displaced

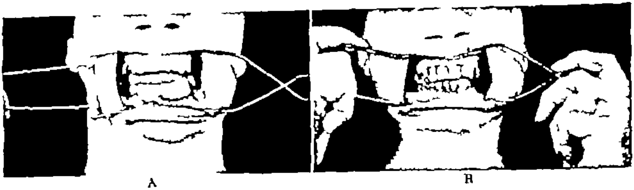


A B

FIG 993

A. Malunited fracture of the mandible with open bite on one side.

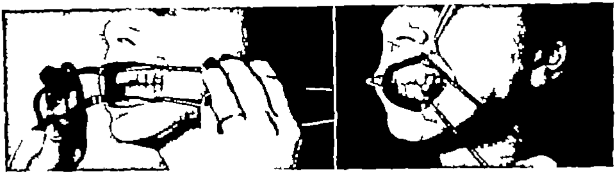
B The mandible was sectioned through the symphysis and the right side was raised to bring the lower incisors into more normal relationship with the teeth of the maxilla.



A B

FIG 994

A. Open-bite following malunited fracture of the mandible. Only the last mandibular molars are in contact with the teeth of the maxilla.
B. The mandible was sectioned and the teeth were placed in correct occlusion



A B

FIG 995

A. Photograph showing malunited fracture of the mandible The patient sustained bilateral fracture of the condyle necks with backward displacement of the mandible.
B. Improved relationship of jaws and teeth following osteotomy of the body of the mandible.

because of the retrusion of the maxilla it is good surgical practice to correct the condition by osteotomy In edentulous patients restoration of contour by onlay bone grafts may be the preferable method of treatment. (see Fig 988)

Osteotomy is indicated in all partly or recently consolidated maxillary fractures and is successful in all types of fractures when performed during the first four or five weeks following injury Subperiosteal exposure of the maxilla can be obtained through the intraoral approach and through small external incisions in the lower lid and lateral border of the orbit. A narrow tipped osteotome is employed to section through the fracture lines, the bone is grasped with a strong forceps, the remaining attachments are fractured and the bone is replaced bodily in the corrected position. Intermaxillary fixation assures maintenance of the dental occlusion. A traction headgear establishes upward pressure beneath the mandibular symphysis and maintains cranial contact of the maxilla until bony consolidation occurs. Good results have been obtained by osteotomy of the lower maxillary segment (Figs. 989 and 990) in a long-established consolidated malunited fracture of the maxilla. The possibility of a fracture line radiating backward into the optic foramen and the danger of blindness is a sobering influence when considering a secondary osteotomy which involves the orbital cavity When the state of the patient's dentition justifies correction of the malocclusion we prefer an osteotomy of the lower maxillary segment followed by contour restoration with bone

grafts of the anterior aspect of the body of the maxilla nose infraorbital and zygomatic regions.

Open Bite Deformities of the Jaws

The term open-bite refers to a condition in which the anterior teeth fail to occlude when the jaws are brought together and the posterior teeth are in occlusion. When the open-bite is due to an abnormal configuration of the body of the mandible correction of the condition can be achieved only by surgery

The extent of malocclusion of the teeth in inadequately treated jaw fractures (Fig 994) depends on the location and severity of the bone injury The most frequent causes of open-bite are

1 Bilateral fractures of the rami especially at the level of the necks of the mandibular condyles, invariably cause backward and upward displacement of the mandible occlusal contact of the dentition occurs only in the region of the last molars.

2. Localized open bite conditions from maltreated fractures of the body of the mandible are not as serious as other types of open-bite but masticating efficiency is diminished.

3 Fractures of the bones of the middle portion of the face, the maxilla being displaced backward and upward

4 Untreated fractured jaws in children may not indicate much deviation from the normal initially a developmental increase in the deformity occurs however the open bite becoming more apparent as the child grows older

5 Downward distortion of the mandible from the constant pull of contracted scars of

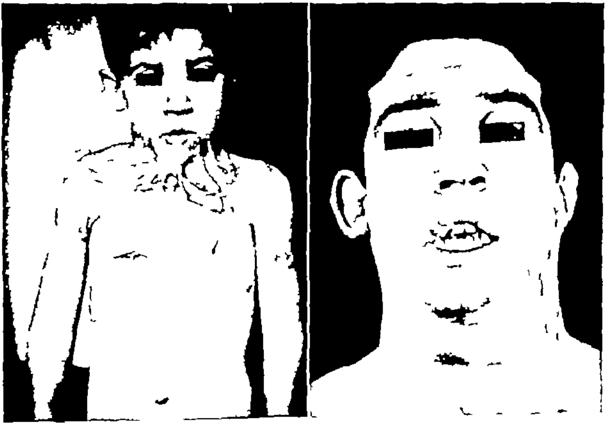


FIG 996

A. Photograph of a child with extensive burn scars and contractures of the neck.

B. Photograph of the same patient as an adult. The neck contracture has been relieved mandibular prognathism and open-bite are the result of the traction on the mandible after long-standing scar contracture

(FIGS. 996 and 997 from V H Kazanjian. *Fortschritte der Kiefer- und Gesichts-Chirurgie* G Thieme Stuttgart, 1956)

the neck may also be included among the causes of open bite (Fig 996)

Surgical Treatment of Open Bite

A study of casts of the dentition mounted on a mechanical articulator discloses three different types of open bite. The most simple type shows only vertical displacement (Fig 994) The second is associated with prognathism (Fig 996) The third type is characterized by open bite plus retrusion of the mandible.

1 The operative procedure of the first type (neither complicated by prognathism nor by retrusion of the mandible) consists of making a vertical cut on each side of the mandible anterior to the posterior teeth and raising the anterior segment of the mandible to the desired occlusion, thus closing the bite. Postoperative immobilization is achieved by intermaxillary wiring (Fig 997)

2. In open bite conditions complicated by prognathism, section of the body of the mandible is preferable to ramus section. A measured section of bone is removed from each side, the anterior portion of the jaw is raised until the dental relationships are re-established and the jaws are immobilized.

3 When there is retrusion of the jaw in addition to open bite, the operative procedure as well as the problems attending postoperative care are more complicated. The body of the mandible must be elongated and retained in a more normal relationship to the maxilla A reverse L-shaped line of osteotomy is made through the body of the mandible and the fragments are fixed in the desired position. More precise means of retention are necessary for success in such cases In addition to intermaxillary fixation, maximum forward thrust of the chin is obtained by the use of an external appliance which exerts a precise amount of pull on the symphysis (see Fig 931*F*)

DEFORMITIES DUE TO LOSS OF BONE AND SOFT TISSUES

Bone grafting is indicated in the following types of cases (1) non union of the mandible (2) when a definite gap exists in the continuity of the mandible and (3) when it becomes necessary to restore the contour of the mandible to improve the shape of the lower part of the face.

Fig 997 X-ray of open-bite condition, showing the degree of the open bite. Arch wire cables have been applied to the dentition for postoperative control of the jaws.

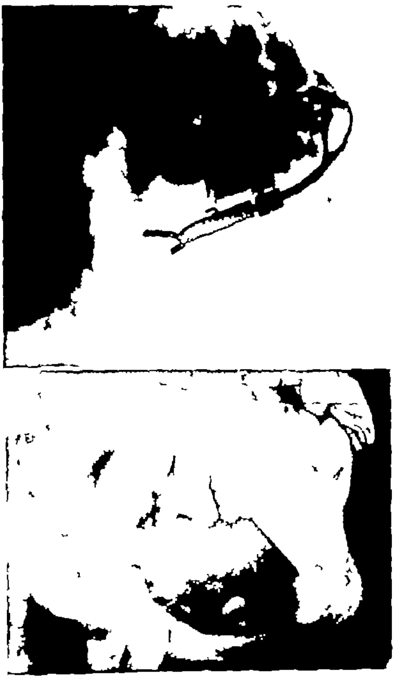
Transplantation of bone should be undertaken only after all evidence of infection has disappeared from the wound. The graft must be placed in a bed of well vascularized soft tissues, in contact with healthy bone denuded of its periosteum and the remaining fragments of the mandible must be immobilized

Methods of Fixation

Various methods of immobilizing fragments following fracture of the mandible with loss of bone substance have been described in Chapter 6 When teeth are present in the remaining fragments (Class I fractures, see Chapter 6) immobilization is best achieved by an intraoral fixation appliance, thus permitting early movement of the jaw The appliance should be strong enough to provide complete immobilization and should be carefully adjusted and fastened to

the remaining teeth to insure secure anchorage both during and after the operation

Supplementary intermaxillary wiring is advisable to relieve some of the stress placed on the appliance, and to prevent breaking or loosening it during the operation If the appliance is provided with an intermediary lock-bar (see Fig 124 Chapter 6) the bar is removed before the operation and each mandibular fragment is wired to the teeth of the maxilla. The lock bar is replaced following completion of the operation The intermax



A

B

Fig 998

A. Roentgenogram showing forked wire splint for immobilizing posterior fragment in a case of loss of one side of the body of the mandible A Jack-screw permits adjustment of the amount of pressure applied by the appliance to the anterior border of the ascending ramus.

B. Roentgenogram of same case as shown in (A) three years after bone transplantation.

(From V H. Kazanjian. Am. J Surg 43 249 1939)

FIG 999 Roentgenogram showing a bite block used to maintain position of the posterior fragment during bone grafting procedures.

illary wires are removed a few days later and the mandibular fragments are immobilized by the lock-bar alone

When teeth are present on only one side (Class II fractures) the control of the posterior fragment can be accomplished by a number of methods. An intraoral appliance with a forked wire attached to it is employed to immobilize the edentulous fragment until the bone graft is in place (Fig 998 see also Figs. 149 150 190 and 191 Chapter 6) The graft is wedged into position between the anterior and posterior fragments to prevent forward displacement of the posterior fragment. It is also possible to hold the posterior fragment in position with a bite-block (Fig 999)

When loss of bone occurs in the retromolar region of the mandible the posterior fragment is usually displaced medially increasing the gap between the ends of the bones and resulting in a depression of the side of the face.

External fixation may be indicated in certain cases to maintain the position of the edentulous posterior fragment (see Figs. 190 and 191 Chapter 6) Figure 1000 shows ex

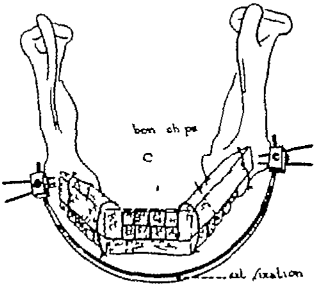


FIG 1000 Immobilization of two posterior edentulous fragments by external fixation appliance during bone grafting

(Figs. 621 to 624 from J M. Converse, J Oral Surg., 3 112 1945)

ternal fixation for bilateral control of the displaced rami when bone grafting is necessary in total loss of the body of the mandible.

Immobilization is further provided in total loss of the body of the mandible by bone grafts wired to the remaining fragments and to one another (Figs. 1001 and 1002)

Prior to bone grafting external fixation appliances retain the edentulous fragments in position After bone is transplanted and fastened with wires to the proximal ends of the mandibular segments, additional fixation methods are not required for the interosseous wires and the bone grafts are usually firm enough to maintain the parts.

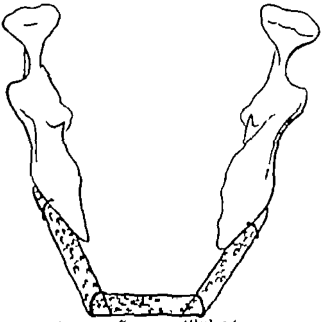


FIG 1001 Diagram showing reconstruction of the missing mandibular arch by three bone grafts wired to each other and to the posterior mandibular fragments.

While careful carving and fitting of bone grafts, using circular electric saws and drills, gives one a gratifying sense of technical perfection simpler methods of grafting suffice if adequate contact with adjacent bone fragments can be established.

Defects of the Body of the Mandible

When the gap between the two fragments of bone is narrow as in non united fractures, a small incision is made below the lower border of the mandible and the ends of the fragments are exposed by reflecting the periosteum. The bone is trimmed with rongeur and osteotome, and bone chips from the crest of ilium are placed between the fragments (Fig 1003) An additional bone graft over the fragments bridges the gap. The intraoral approach may also be employed in such defects. Cancellous chip bone grafts are

FIG 1002. Roentgenogram showing mandibular bone grafts wired together as in Figure 1001

preferable to a single bone graft, for it is generally acknowledged that they are more resistant to infection

A larger defect requires a larger graft from the iliac bone shaped to overlap the ends of the fragments and wired to them (Fig 1004) The surface of contact between graft and host bone should be as large as possible. Interstices between the transplant and the mandible are filled with bone chips. The curvature of the iliac crest supplies a suitable graft for it simulates the curvature of the mandibular arch

In extensive loss of bone involving the symphysis and part of the body of the mandible, reconstruction has been accomplished by the use of three large iliac bone grafts one median graft in the area of the symphysis and one on each side. The bone grafts are wired to each other and to the posterior mandibular fragments (Figs. 1001 and 1002)

Extensive loss of bone in the mandible occurs most frequently in gunshot wounds of the jaws and is accompanied by a great amount of soft tissue damage The reconstruction of such cases is discussed later in this chapter Marked loss of bone without soft tissue loss is occasionally seen. The patient shown in Figures 1005 and 1006 lost the greater part of the body of the mandible following severe comminution by a shell fragment. Reconstruction by bone grafts was completed by a technique similar to the one shown in Figures 1001 and 1002. After the bone grafts had consolidated a new buccal sulcus was made by a skin graft (Fig 1006*A*) permitting the insertion of a denture (Fig 1006*B*)

When a large bone graft is required, the ends of the bony fragments can be exposed through small incisions below the mandibular border establishing a tunnel between the two openings for insertion of the transplant (Fig 1007*A*) If difficulty is encountered in passing the bone graft through this tunneled area a large Penrose drain may be used (Fig 1007*B*). The graft is eased through and the drain is removed after the graft is in position This procedure permits the introduction of large pieces of bone through a small external opening

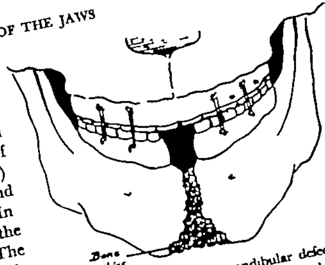


Fig 1003 Filling small mandibular defects with cancellous bone chips. The chips are packed into the interosseous space after the ends of the fragments have been resected with a rongeur

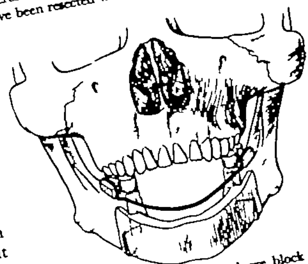


Fig 1004 Diagram showing large block of iliac bone carved fitted and wired to the remaining mandibular fragments. A lock bar appliance, shown in the figure, serves to immobilize the fragments before operation and as additional fixation following bone transplantation.

Defects of the Angle and Ascending Ramus

The angle and ascending ramus of the mandible may be restored with a graft from the inner table of the iliac crest (Fig 1008) from the side of the body opposite that of the mandibular defect. A graft removed in this manner includes bone from the medial aspect of the iliac crest, comprising the anterior superior iliac spine and a portion of

FIG. 1005

A. Photograph of patient showing loss of the greater portion of the body of the mandible as a result of injury by a shell fragment. This case illustrates loss of mandibular bone with little loss of external soft tissues.

B. The patient demonstrates the loss of the body of the mandible by pressing the soft tissues backward.

C and D. Appearance of patient following completion of bone grafting, epithelial inlay and full denture.

Fig 1006

A. A view of the oral cavity of the case shown in Figure 1005. The body of the mandible has been restored by a bone graft, and a sulcus formed with a skin graft to establish a site for retention of a lower denture.

B. Shows the lower denture in the mouth.

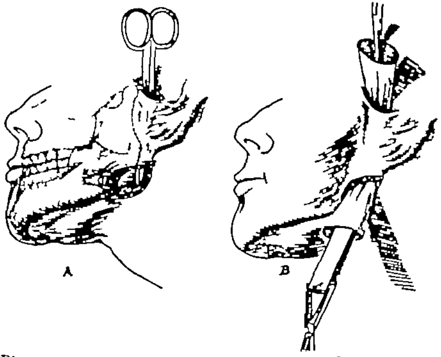


Fig 1007 *Diagrams showing method of introducing large bone graft through two small incisions*

A. A tunnel joins the two incisions. A forceps is placed ready to grasp a Penrose-type drain.

B. The Penrose drain has been placed and the bone graft is introduced through the drain. The drain is withdrawn after the bone graft is fitted into position.

(From V H. Kazanjian, J Bone & Joint Surg 21:761 1939)

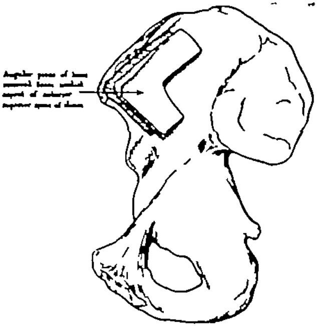


Fig 1008. Drawing of the ilium showing an angular piece of bone taken from the medial aspect of the antero-superior spine on the side opposite that of a mandibular defect shown in Figure 1009 This angular piece is of suitable shape to restore the angle and ramus of the mandible, as shown in Figure 1009*B*

(Figs. 1008 and 1009 from J M Converse J Oral Surg., 3-112, 1945)

the inner iliac table below the spine. The cancellous surface of the graft affords a wide area of contact for it overlaps the remaining mandibular bone (Fig 1009*B*) An incision is made at the level of the lower border of the masseter muscle (Fig 1009) The absence of mandibular bone results in an intimate relationship between the masseter and the internal pterygoid muscles. The plane of cleavage lies between these two muscles Either the lingual inferior alveolar or mylohyoid nerves can be visualized lateral to the internal pterygoid muscle (Fig 1009*A*) thus indicating the plane of cleavage. In order to facilitate exposure of the remaining portion of the ascending ramus, it is often necessary to make a second pre-auricular incision approaching the bone by way of this route. The bone graft is securely wired to the posterior portion of the body of the mandible (Fig 1009*B*) the graft overlies the remaining portion of the ramus. Bone chips may be added and the soft tissues are sutured. The lower border of the masseter muscle is sutured to the platysma. Immobilization is provided by means of intraoral fixation appliances with an attached flange which by preventing lat

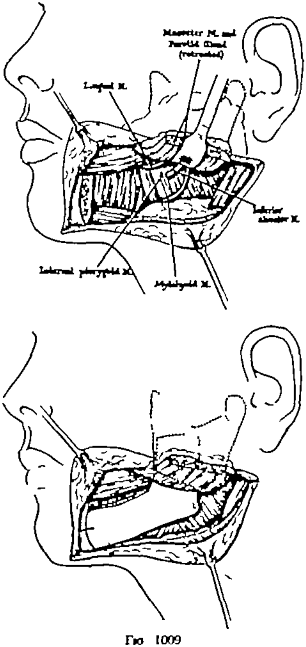


Fig 1009

A. Drawing showing loss of the angle and ascending ramus of the mandible to be restored by a bone graft from the ilium. The dotted line shows the outline of the remaining portion of the ramus. The plane of cleavage between masseter and internal pterygoid muscles is indicated.

B. Angular bone graft fitted and wired to the body of the mandible and overlapping the remaining portion of the ramus.

eral deviation, permits opening of the mouth after approximately six weeks. Figure 1010 shows photographs and roentgenograms of a patient who had suffered the loss of the entire right side of the mandible.

The following case of congenital absence of both mandibular rami (Fig 1011) is included to demonstrate the surgical technique of restoring the missing bone in conditions similar to the effects of gunshot wounds or other trauma.

The facial contour revealed a markedly retracted chin and conspicuous depression on each side of the face over the region of the angles and rami of the mandible (Fig 1011*A B*) The mandible was floating and could be easily manipulated in any direction. The teeth were in good condition Upon chewing, the movements of the jaw were unpredictable due to the lack of ascending rami and there was no appreciable grinding action of the teeth, although the masseter and internal pterygoid muscles seemed unimpaired The muscles of facial expression displayed no weakness.

X rays revealed slightly more bony devel

A

B

C

D

Fig 1010

A and B Photograph and roentgenogram of patient with absence of entire half of the mandible.

C and D Photograph and roentgenogram showing bone graft extending from the temporomandibular joint to the median line of the mandible, restoring the entire ramus and half of the body of the mandible.

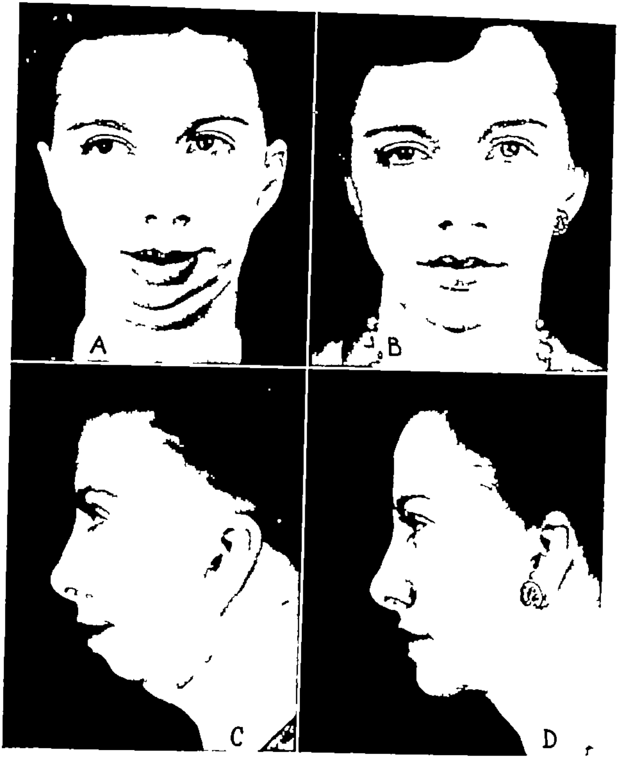


Fig 1011 Bilateral absence of the mandibular ramus

A and C. Preoperative appearance of the patient showing marked retraction of the chin and depression of the lateral aspects of the face. The transverse fold below the chin is due to hypertrophic bone of the body of the mandible (see Fig 1012)

B and D Postoperative appearance of the patient.

(Figs. 1011 to 1012 from V H Kazanjian Brit. J Plast Surg 9 77 1956)

opment on the left than on the right side but disclosed neither rami nor mandibular condyles on either side (Fig 1011*A B*) The zygomatic processes of the temporal bones had failed to develop the zygomatic bones were normally outlined The hyoid bone appeared large and irregular The body of the mandible was overdeveloped vertically and

the cortical border was greatly thickened giving the external appearance of a transverse shelf across the front of the neck above the thyroid cartilage. It was postulated that this hypertrophy may have resulted from over use of the suprahyoid muscles in achieving opening of the mouth since the external pterygoid muscles appeared to be absent.

The jaws were wired together temporarily in occlusal relationship A 5 cm incision in the region where the right angle of the jaw should have been was extended downward to expose the body of the mandible. The masseter muscle was found to be poorly developed the angle of the jaw was small and a rudimentary ascending ramus which measured about 0.5 cm in diameter at the angle tapered off to nothing after a short distance upward toward the zygoma Because of the difficulty in following a line of cleavage between the masseter and internal pterygoid muscles and the region of the glenoid fossa, an additional incision was made in front of the right auricle. The zygomatic arch was identified and the periosteum separated down toward the region where the glenoid fossa should have been The opening thus established was connected with the first incised area beneath the parotid and enlarged preparing a tunnel for the reception of a bone graft.

The right iliac crest was exposed and two large sections of bone and several smaller sections were removed from the crest to be used as "fill A section of bone was then implanted beneath the parotid gland in the prepared tunnel the implant extending from the rudimentary glenoid fossa to the posterior portion of the right body of the mandible where the bone graft was wired firmly to the body with two stainless-steel wires. Several smaller chips of bone were planted in strategic areas to reconstruct the angle of the jaw and to add fullness where required.

An incision similar to that on the right side, was made below the body of the mandible on the left side and the bone was exposed Anomalous conditions found on the right side were also present on the left. The lower end of this transplant was wired directly to the posterior portion of the body as on the opposite side and several bone chips were also implanted where indicated. Both wounds were closed in layers. The intermaxillary wires were then removed and the teeth were retained in satisfactory temporary occlusion by means of elastic bands and maintained for approximately six weeks X rays revealed that bone grafts to replace the ascending rami articulated with the base of the skull and that there was good union at the points of contact with the bony rami (Fig 1012)

Five months after the initial surgical procedures the dental occlusion still remained in the desired relationship and the patient could chew food with no difficulty Although a slight grinding action of the teeth could be detected during mastication the patient

FIG 1012

A and B. Roentgenograms showing the rudimentary ramus on each side.
C. Roentgenogram showing the bone grafts articulating with the base of the skull.

could control mandibular motions effectively

Although satisfactory function of the mandible had been achieved and the depressions on each side of the face had been corrected the retracted appearance of the chin had not been appreciably altered. Two subsequent operations were therefore performed to restore facial contour transplanting additional iliac bone to the region of the chin and to the sides of the mandible

A third operation was performed to at

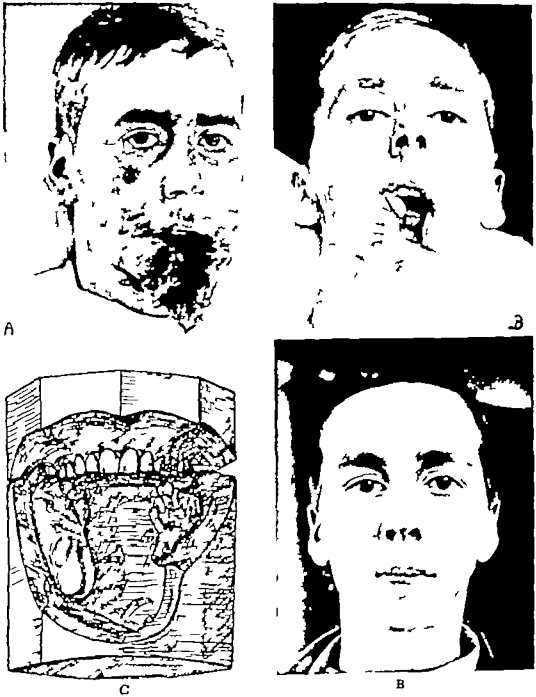


Fig. 1013

A. Photograph showing the result of a firearm injury with loss of a large portion of the body of the mandible, lower lip, chin and skin of the suprahyoid area

B. Photograph after primary healing

C. Drawing of plaster casts of the dentition showing the intraoral condition of the patient.

D. Result obtained following reconstruction of bone and soft tissue.

tain still further and more detailed contour restoration. Again bone was removed from the iliac region some of this bone was transplanted to the chin to accentuate the mental prominence. Other portions of bone were added to the left side of the jaw to create an appearance harmonious with that of the right side (Fig 1011*B* *D*)

Bone Defects Associated with Loss of Soft Tissue

Injuries of the lower part of the face with loss of varying amounts of soft tissue including the lip chin and sublingual tissue associated with loss of mandibular bone are usually the result of gunshot wounds or of severe injuries occasionally seen in industrial accidents (Figs. 1013 1014 1016 and 1017)

The initial goal in the correction of such deformities is adequate control of the bony fragments Although the external wound may give the appearance of almost total destruction of the underlying skeletal frame work a sufficient amount of bone is almost always present to be used as a foundation for future reconstruction. This may include a part of the body of the mandible on each side, with or without teeth or may consist of only the rami.

Utilization of the mandibular fragments is the first essential step in reconstruction of the face and jaw Unless fixation of these bony segments is provided at an early date displacement complicates subsequent reconstructive procedures. If this procedure is neglected the ramus is displaced forward, upward and medially and must be located and freed from the soft tissue attachments at the time of operation

When teeth are available and the fragments can be manipulated, intraoral fixation appliances can be constructed to maintain the separated portions of the mandible in their anatomical positions

It is obvious that bone transplantation must be delayed until the soft tissues of the

A B

FIG 1014

A. Photograph showing extensive loss of the mandible and soft tissues of the lower lip and chin. Immobilization of the lateral fragments of the mandible by a band and arch wire splint.

B. The removable mold acts as a framework for the future lip.

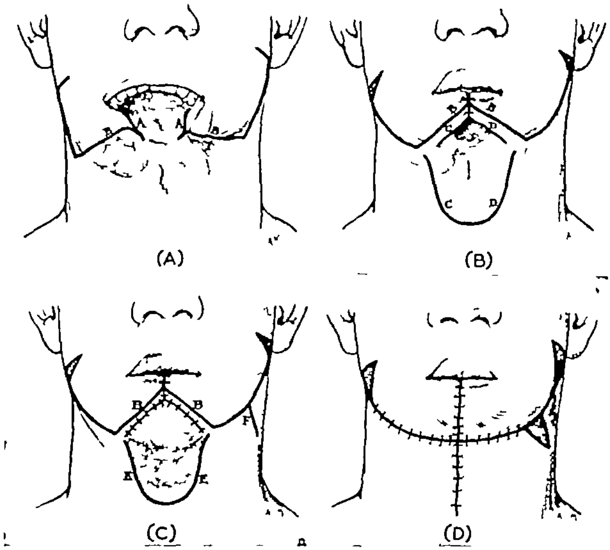


FIG 1015. Diagrams illustrating the utilization of large rotation flaps of the cheeks and a delayed flap from the neck to reconstruct the lower lip and chin

A Outline of rotation flaps.

B. The flaps are brought together to form the upper part of the lower lip the outline of the delayed chin flap is also indicated.

C. The chin flap is raised, turned in, and sutured to form the inner lining of the mouth.

D Defect covered by approximation of skin borders.

(Figs. 1015 and 1016 from V H Kazanjian, J Oral Surg 1 30 1943)

lip and chin become revascularized and softened During an interval of a number of months, definitive fixation appliances and supporting molds should be provided to control the remaining parts of the mandible and to act as a temporary framework of support for the reconstructed lip and chin tissues (Figs. 1013*B* and 1014 see also Chapters 4 and 6)

The second step in the correction of these extensive defects is the reconstruction of the soft tissues. We favor the following technique which employs the remaining lip and cheek tissue supplemented by a cervical lining flap from the suprahyoid region (Fig 1015)

In most cases, a considerable amount of lip tissue remains and can be utilized Wide rotation flaps are outlined including the remaining portion of the lower lip cheek tis-

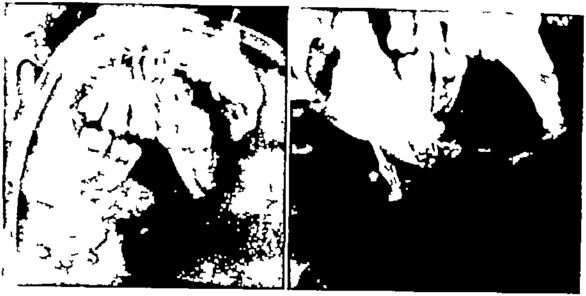
A B

C D

FIG 1016

A and B. Photographs of patient when first seen fifty-six days after being accidentally shot while hunting. A large portion of the lip, chin, and body of the mandible was destroyed. These photographs stress the fallacy of primary suturing without providing adequate supporting appliances for the soft tissues.

C and D. Photographs after completion of treatment. The second operation (performed fifteen days after the first) consisted of bringing two large rotation flaps forward from each side of the face to form the lower lip, a procedure similar to that shown in Figure 1015. A delayed chest flap was used to reform the inner lining of the mouth and to cover a portion of the neck (see Figs. 1017 and 1020). In subsequent operations an iliac bone graft was transplanted to the mandible and the contour of the chin was improved.



A B

Fig. 1017

A. Roentgenogram of patient shown in Figure 1016. Extensive loss of bone is seen; two molar teeth remain in each of the posterior fragments.

B. Roentgenogram showing bone graft restoring mandible.

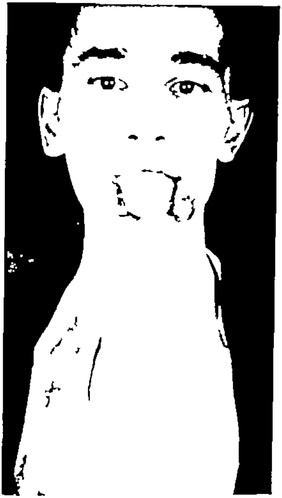
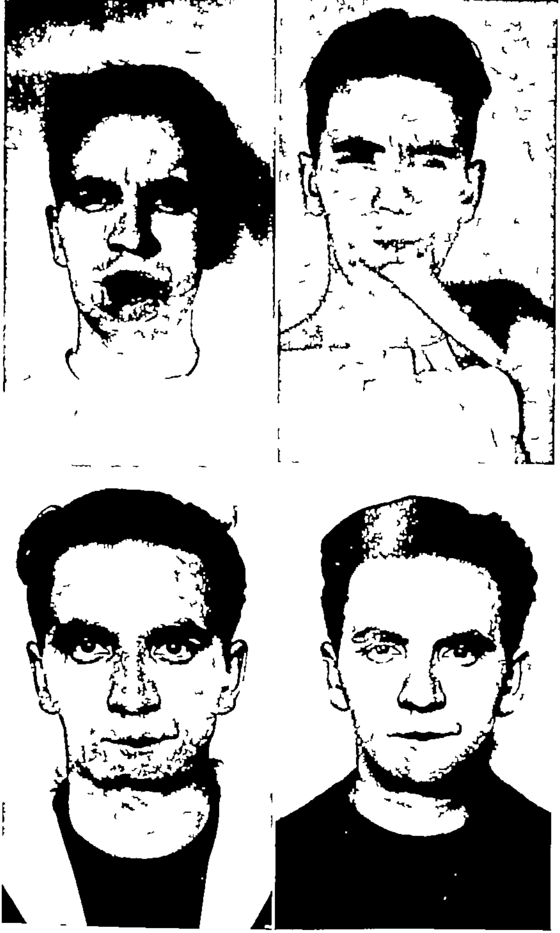


Fig. 1018. Photograph of patient shown in Figure 1016. The delayed pedicled flap utilized for the reconstruction of the inner lining of the oral cavity is seen.

A B



C D

Fig 1019

A. Extensive defect of the lower lip and chin with loss of the median section of the mandible, caused by bomb injury The two lateral mandibular fragments are immobilized in correct occlusal position with a dental fixation appliance.

B. Skin for restoration of the inner lining of the defect is provided by an acromiothoracic tubed pedicled flap.

C. Appearance of patient after the new lining had been placed in the oral cavity and restoration of the outer skin covering by means of large rotation flaps as illustrated in Figure 1015

D Appearance of patient after reconstruction of the mandible by bone grafting

(From J M. Converse, J Oral Surg 3 112, 1945)

sue and the skin from the cervical area (Fig 1015) In male patients, these rotation flaps have the advantage of preserving the continuity of the bearded region.

The replacement of a lining for the inner buccal surface is a more difficult problem Sufficient mucosa is usually available to supply the lining of the upper part of the lip but is not adequate for the lower portion of the lip and floor of the mouth A previously delayed flap of skin may be turned back from the median part of the neck to supply the inner lining (Fig 1015) this procedure is indicated only if the skin does not contain hair follicles. Another procedure for providing the inner lining of the mouth consists of preparing a delayed flap of skin on a hairless area of the chest or arm (Figs. 1018 to 1020) This method is highly satisfactory for in addition to providing a non hairy lining for the mouth the flap may be used to advantage if additional tissue is required for the skin defect

Bone grafting is the third step in the reconstruction of extensive mandibular defects.

Operative procedures which restore the external contour of the face and reestablish the bony continuity of the mandible should be supplemented by artificial dentures which restore masticatory function To insure the retention of dentures in such cases it is always necessary to reconstruct a buccal sulcus (Fig 1006) and adequate alveolar ridges over the transplanted bone The technique of restoring a new buccal sulcus by nitraoral skin grafting is described in Figure 1035 Chapter 25 This may be accomplished effectively by sectioning the soft tissues lateral to the newly formed body of the mandible until the periosteum is exposed a skin graft is then applied

Full thickness loss of tissue of the cheek wall resulting from gunshot wounds, is not as frequent an occurrence as defects of the lips, chin and mandibular body Techniques

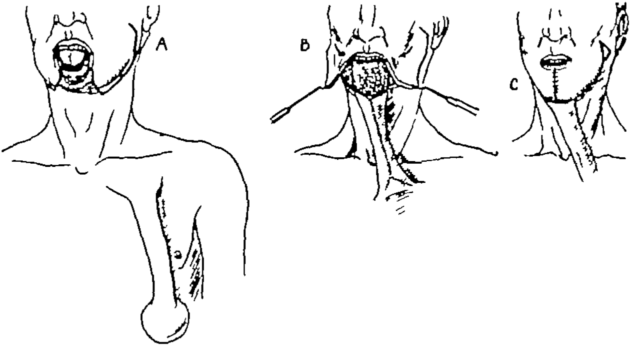


FIG 1020. Thoracic flap for the restoration of the lining of defects of the lower lip and chin

A. Outline of thoracic tubed pedicled flap with delayed racquet extension. Note the rotation flaps on the face

B. The thoracic flap has been turned up restoring the lining of the defect.

C. The rotation flaps have been transferred to cover the defect

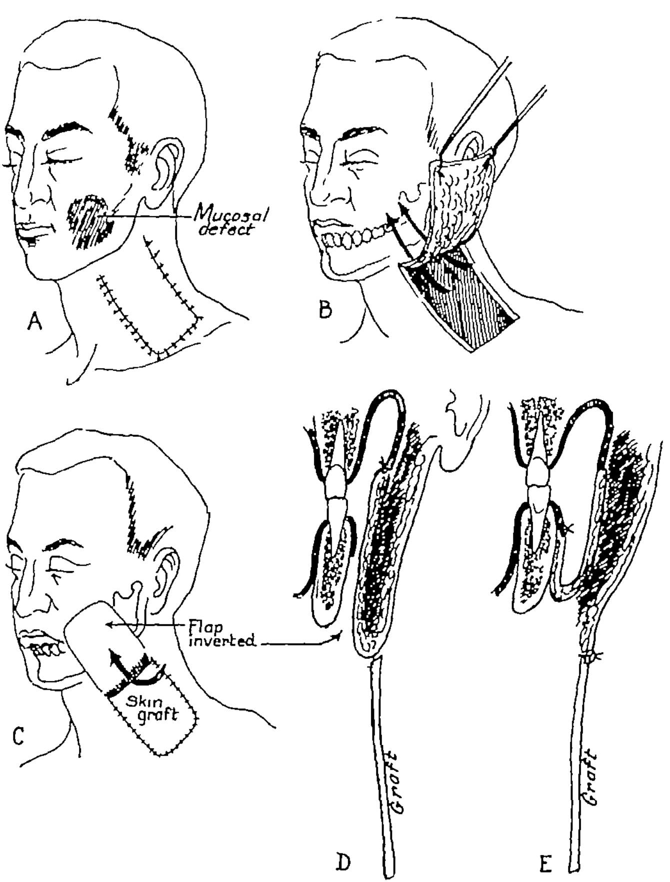


FIG 1021 Restoration of the lining of the cheek wall by cervical flap

A. Outline of delayed flap.

B. Flap raised.

C. Flap turned into the oral cavity through a submandibular incision.

D. Sectional view illustrating manner in which the flap is folded into the oral cavity

E. In a later stage the pedicle of the flap is severed and the remainder of the flap serves to restore the buccal sulcus.

for reconstructing such defects are described in Chapter 23

Deficiency of the lining mucosa of the cheek wall and scar tissue bands do not permit complete opening of the mouth The replacement of the mucosal lining by means of skin grafts may be unsatisfactory in larger defects because of the progressive contraction of the skin graft in the badly scarred cases. A technique which has given satisfactory results is illustrated in Figure 1021

25

RECONSTRUCTIVE SURGERY OF THE ORAL CAVITY AND PHARYNX

The surgical treatment of traumatic lesions which affect oral structures and result in interference with normal function are outlined in this chapter Such deformities include contour changes of the alveolar processes, obliteration of the buccal sulcus, palatal defects adhesions of the tongue scar contractures of the buccal mucosa preventing proper movement of the jaws, scar constrictions of the oropharynx and nasopharynx, and defects of the jaws due to malunited fractures.

SURGICAL PREPARATION OF THE MOUTH FOR ARTIFICIAL DENTURES

When all or part of the alveolar ridge has been destroyed, or the buccal sulcus has been obliterated by scar tissue or adhesions or by absorption of underlying bone the sulcus must be re-established to retain an artificial denture.

Bony spines and exostoses, often the result of injury during extraction of teeth or from other types of trauma, result in minor changes in alveolar contour Fracture or surgical removal of alveolar bone results in a reduction in height of the buccal sulcus, and when soft tissue has also been destroyed, scars and adhesions form between the buccal surface of the lip and the alveolar crest.

The buccal and labial folds of the vestibular space are determined by the areas of origin of facial muscles these include the buccinator caninus, quadratus labii superioris and inferioris zygomaticus nasalis, incisivus labii superioris and inferioris depressor septi mentalis, and triangularis muscles (Fig 1022*A*) The peripheral borders of artificial dentures are limited by the attachments of these elastic structures.

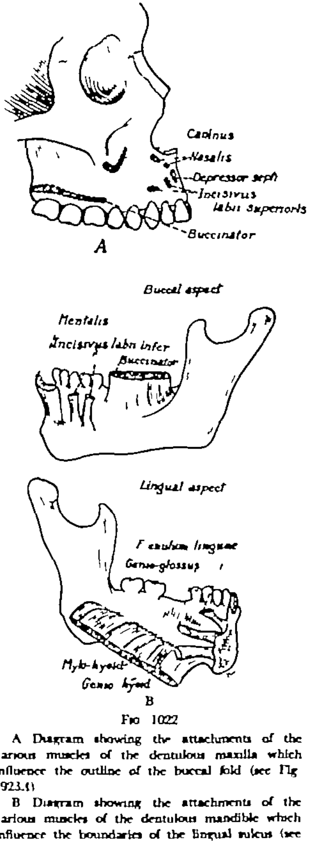
The buccinator mentalis, quadratus triangularis and depressor labii inferioris muscles form the principal boundaries in the anterior part of the buccal fold in the lower vestibular space (Fig 1022*B*) Structures attached to the inner surface of the mandible, limiting the extension of the lingual borders of lower dentures include the genioglossus and the mylohoid muscles. Owing to the absorption of alveolar bone following the loss of teeth these structures are located closer to the crest of the ridge, thus limiting the peripheral extensions of the denture flange (Fig 1023)

Alveolar prominences are exposed through an incision in the overlying mucosa the protruding area of bone is then excised as shown in Figure 1024*C D* Casts of a dental ridge improved by excision of irregular protuberances are seen in Figure 1024*A B*

Prominent Alveolar Ridges

The gingival fold must be preserved for denture retention when abnormally prominent alveolar ridges of the maxilla are removed (Fig 1025) An incision is made along the prominent margin down to the bone. The soft tissues are elevated on the lingual side and up to the anterior nasal spine and

canine fossa on the labial side Excess bone is removed with a rongeur (Fig 1026) the labial tissues are extended upward, and the wound edges are approximated. The removal of bone permits sliding the labial flap to a higher position this is maintained by



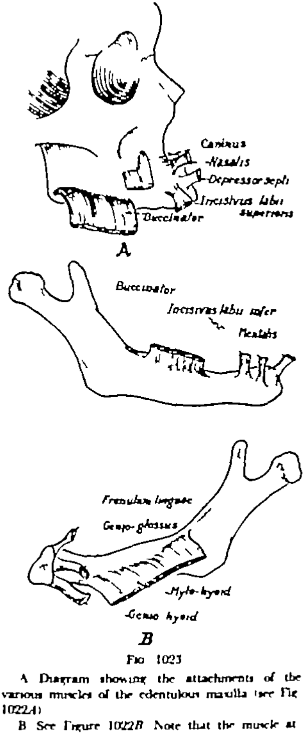
B

Fig 1022

A Diagram showing the attachments of the various muscles of the dentulous maxilla which influence the outline of the buccal fold (see Fig 1923A)

B Diagram showing the attachments of the various muscles of the dentulous mandible which influence the boundaries of the lingual sulcus (see Fig 1023B)

(Figs 1022 to 1027 and 1030 to 1033 from V H Kazanjian, Am. J Orthodontics and Oral Surg 26 263 1940)



B

Fig 1023

A Diagram showing the attachments of the various muscles of the edentulous maxilla (see Fig 1022A)

B See Figure 1022B Note that the muscle attachments are closer to the dental ridges in the mouth without teeth

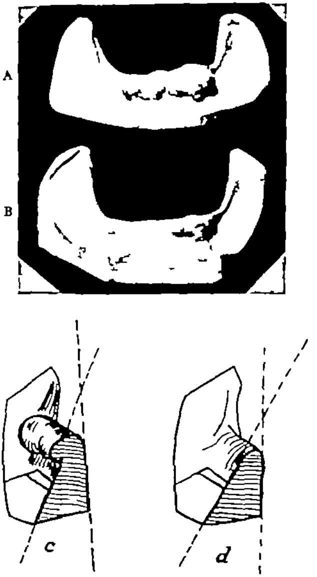


FIG 1024

A. Photograph of a plaster cast of an edentulous lower ridge showing prominence of the dental ridge.
B. The dental ridge shown in (A) following surgical resection of the prominence.
C. Diagram showing overhanging dental ridge.
D. Result after trimming the dental ridge.

placing a small flexible rubber tube under the lip and passing interrupted mattress sutures around it and through the lip (Figs. 1026 and 1027) Because the sutures exert a pull on the mucosa they are tied over gauze to prevent cutting the skin

Fibrous Bands

Fibrous bands such as the labial frenulum occasionally interfere with the adaptation of an artificial denture these are removed by an incision extending from the base of the adhesion toward the buccal fold (Fig 1028) the raw surface following the excision of the fibrous fold is repaired by suturing the borders of the mucosa together A horizontal incision along the buccal sulcus aids in approximating the borders. Although a raw surface remains over the alveolar ridge, the tissue heals without distortion since one side is covered with normal mucosa

Another method for obliterating fibrous bands is a modification of the Z plasty used for the repair of web-like adhesions resulting from scar tissue in other parts of the body A vertical incision is made along the length of the web and the tissues on both sides of the incision are undermined freely Two lateral incisions are then made to outline the flaps one incision extends close to the alveolar ridge and the other to the mucosa of the cheek the three incisions thus resemble the letter Z. The flaps are then transposed and sutured thus obliterating the fibrous band without leaving any raw areas (Fig 1029)

Vertical Extension of the Maxillary Alveolar Ridge

Absorption of the alveolar ridge due to loss of teeth reduces the size of the buccal or labial sulcus hypertrophy of the alveolar mucosa may accompany this condition most frequently seen in the maxilla

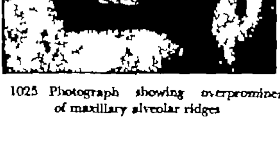


FIG 1025 Photograph showing overprominence of maxillary alveolar ridges

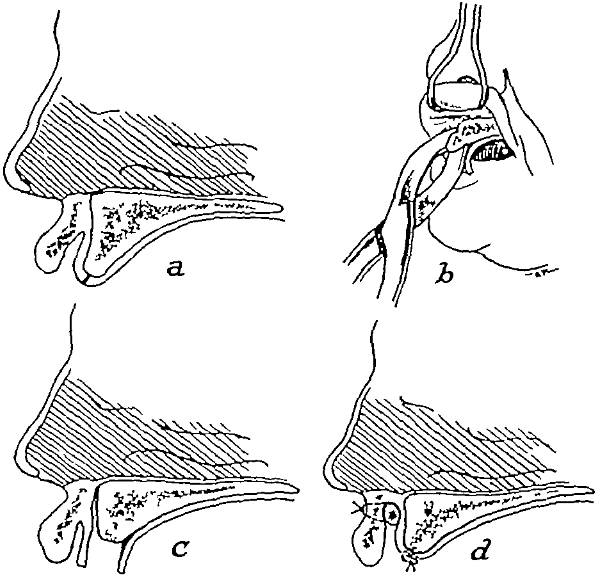


Fig. 1026. Diagrams showing various steps in surgical resection of prominent alveolar ridges.

A. An incision is made through the crest of the alveolar process and the bone is freely exposed.

B. The prominent ridge is then excised.

C and D. Instead of removing the excess mucosa on the buccal side it is undermined freely toward the nasal spine and canine fossa, and the buccal mucosa is raised to its new position.

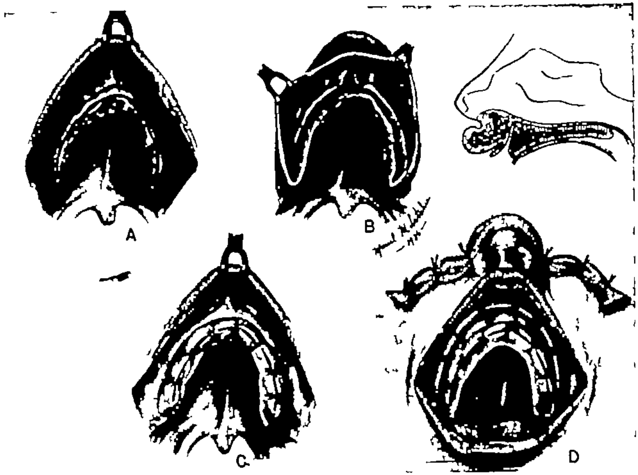


FIG 1027 Drawings showing progressive steps in the surgical resection of prominent alveolar ridges, and the establishment of a new labial and buccal sulcus for the retention of an artificial denture.

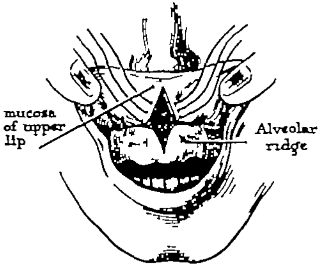


FIG 1028. A fibrous band over the center of the alveolar ridge is repaired by an incision along the base of the adhesion and the loose ends are sutured together As one side is covered with normal mucosa the raw surface will heal without appreciable distortion

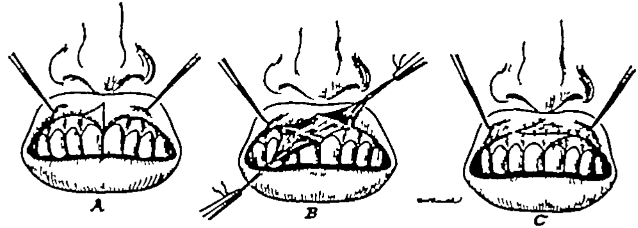


Fig 1029 Drawings illustrating correction by Z flaps of a contractile band over the center of the alveolar ridge

A Outline of Z flaps.

B. Z flaps raised.

C. Z-flaps transposed.

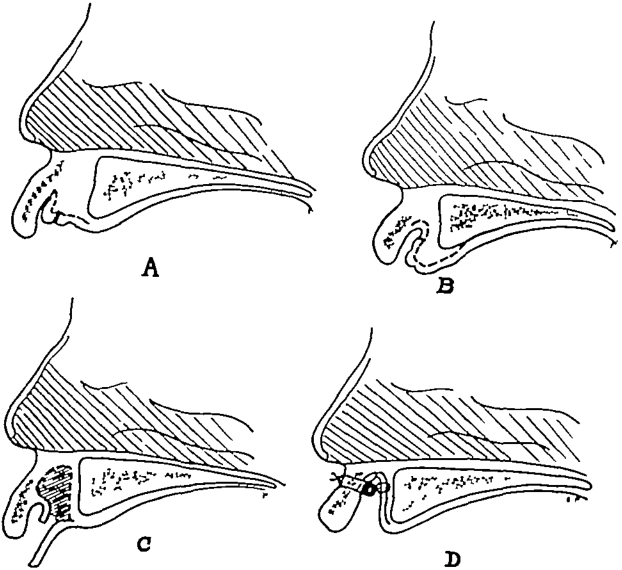


Fig 1030. Diagrams illustrating various steps and the proper method of trimming a flabby alveolar ridge

A. Sagittal section of alveolar ridge showing flabby tissue formation over the ridge

B. The line of incision through the mucosa covering the flabby tissue

C. Following the incision shown in (B) the two folds of mucosa are separated, exposing the underlying flabby tissue which is then excised.

D Each fold is raised and sutured to the periosteum overlying the outer alveolar bone high in the mucobuccal fold thus forming a deep sulcus and an extended alveolar ridge

Surgical correction consists of extending the buccal and labial sulcus in order that a denture may rest upon a deeper residual ridge. In cases of hypertrophy in addition to extension of the ridge the flabby tissues over the ridge are also eliminated

The removal of flabby tissue should not be confined to mere excision since that would result in a flat surface without the necessary buccal extension of the ridge. The operation should not only eliminate the excessive flabby tissue but should leave well defined borders high in the buccal fold (Fig 1030). If the patient already has a denture it may be relined with dental compound and inserted over the newly formed ridge to aid in maintaining the sulcus thus formed.

The border of the incision on the inner surface of the upper lip is also brought to a higher position and maintained there by suturing to the periosteum or by through and through sutures to the skin (Fig 1031)

Vertical Extension of the Mandibular Alveolar Ridge

The following operation is recommended when fibrous adhesions cover an extensive area over the alveolar ridge of the mandible. A horizontal incision is made on the inner surface of the lip or cheek on a line parallel to the alveolar ridge and about 1.5 cm. external to it along the entire extent of the alveolar ridge (Fig 1032*A* *B*) The loose submucous tissues are separated from the mucosa as far as the alveolar bone, when the mucosa is more adherent this forms a broad flap of mucosa. A vertical incision is then extended downward over the outer surface of the periosteum to a point which corresponds to the distance from the lip and cheek incision to the alveolar ridge. The flap of tissue attached to the alveolar ridge is folded down against the periosteum and sutured at the base of the vertical groove (Fig 1032*D*) The raw surface on the lip and cheek is then closed by approximating the upper and

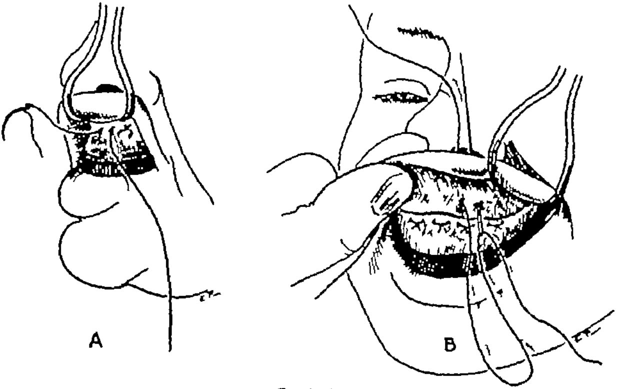


Fig. 1031

A. Diagram showing the flap of mucosa attached to the alveolar ridge and extending over the exposed periosteum, then sutured in place.

B. The edges of the incision inside the lip are raised toward the newly formed groove and retained by mattress sutures passed from the inside of the mouth to the skin.

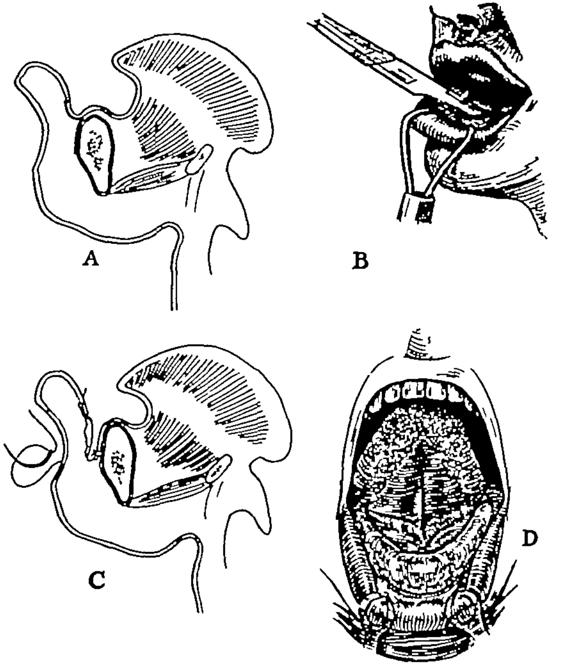


FIG 1032

A and B. A horizontal incision is made on the buccal surface of the lip and cheek on a line parallel to the alveolar ridge and about 1.5 cm. externally

C and D After removal of redundant tissue over the buccal surface of the mandible the flap of mucosa attached to the alveolar ridge is extended over the exposed periosteum and sutured in place

lower margins of the raw area Sutures may be passed through the skin if necessary since because of the elasticity of the mucosa they neither disturb the contour of the lip nor leave permanent scars (Fig 1033). The incision line is extended far enough from the ridge to obtain sufficient covering mucosa for the newly formed ridge Injury to the periosteum must be avoided when suturing the flap

This operation is equally adaptable for reestablishing the buccal sulcus of either the maxilla or mandible

A sufficient amount of mucosa may be un

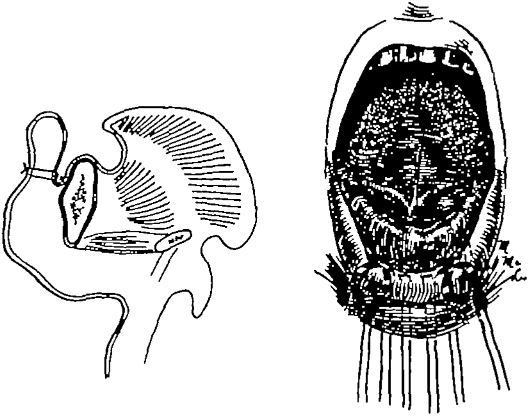


FIG 1033 The edges of the incision inside the lip or cheek are brought down to the newly formed groove, and retained by mattress sutures passed through from the inside of the mouth to the skin, as described in the text.

available for the operation when indurated scars and deep adhesions are present skin grafting is then indicated.

TRANSPLANTATION OF SKIN WITHIN THE ORAL CAVITY

There are many indications for the transplantation of skin within the oral cavity in cases where a considerable amount of mucosa has been lost and replaced by scars and adhesions in comminuted fracture of the jaws with laceration of alveolar mucosa.

Transplantation of skin within the mouth is a practical procedure. The following measures should be faithfully performed however to insure success

1 Complete hemostasis of the raw area must be obtained before applying the skin graft.

2. The skin graft should cover the entire raw area and should be immobilized under moderate pressure.

3 The transplant should be obtained from a hairless area a split thickness graft is usually employed.

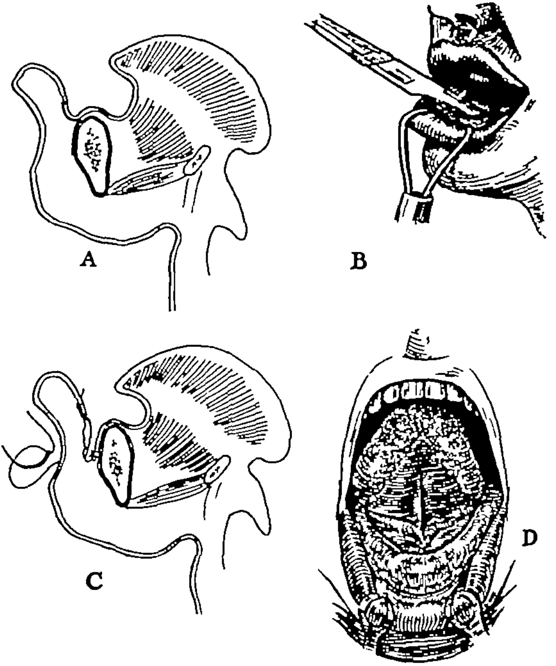
4 Immobilization of the skin graft in the mouth can be accomplished by attaching the graft to a dental compound mold of the raw area The mold carrying the skin graft is immobilized by an appliance in the edentulous mouth other means of fixation must be provided.

Restoration of the Buccal Sulcus with a Skin Graft When Teeth are Present

An incision is made close to the buccal surface of the bone without incising the periosteum The scar tissue is excised and the groove or sulcus formed is made deeper than necessary to allow for subsequent contraction.

Dental compound previously softened in hot water is added to the removable part of an intraoral appliance (Fig 1034) and molded over the newly created buccal sulcus.

A split thickness graft, from a hairless do-



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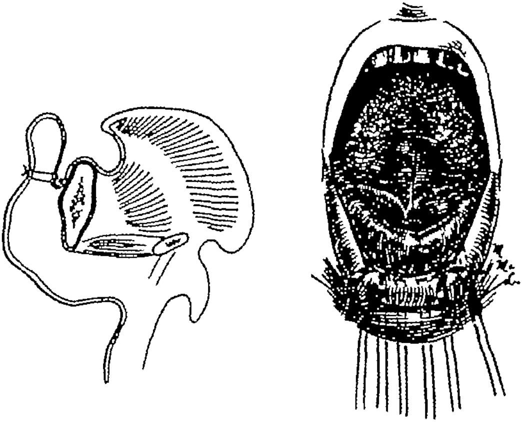

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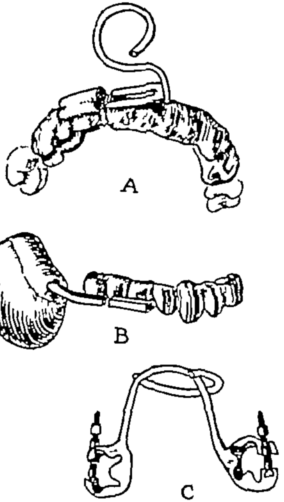

A

B

C

Fig 1034 A dental splint which serves as a carrier and support for a skin graft in the oral cavity

A, B and C. Three types of such splints, each of which consists of a portion fastened to the teeth, and a removable segment which acts as support for dental compound fitted into the prepared sulcus, and which also carries the graft.

(From V H Kazanjian J Am. Dental Assoc. 21 38 1934)

nor area such as the inner aspect of the arm or thigh is wrapped around the compound raw surface outward and is fixed to the compound carrier with dermatome cement. The graft and carrier remain undisturbed for a period of eight to ten days. The mold is then removed the excess overlapping skin graft is excised and the appliance is *immediately replaced* to prevent contraction of the graft and diminution of the sulcus The compound is discarded after approximately one week and is replaced with an acrylic mold or a previously prepared denture with a downward extension into the buccal sulcus which serves as a permanent restoration

At the time of operation duplicate impressions can be made of the surgically created buccal sulcus. One mold serves to immobilize the skin graft the other is duplicated in acrylic and replaces the temporary compound mold. A permanent mold can be constructed at the time of operation by employing quick-curing acrylic the process, however is usually too time consuming

Because of the tendency of the skin graft to contract the permanent appliance should remain in the mouth at all times thereafter to avoid contraction of the graft and stricture of the new sulcus, preventing the replacement of the prosthesis.

Restoration of the Buccal Sulcus with a Skin Graft in the Edentulous Mouth

This procedure presents greater difficulties than in the mouth with teeth. It is sometimes possible to employ the method first advocated by Esser and Waldron (see Chapter 18). The scar tissue is excised from the buccal sulcus, forming a new buccal groove (Fig 1035*A* *B*) into which dental compound is molded The skin graft is wrapped around the mold raw surface out, and placed into the groove. The mold thus forms an inlay which is retained by sutures applied through the soft tissues (Fig 1035C) The following methods are preferred when a larger buccal sulcus is to be grafted.

A bite block is prepared prior to operation The patient's denture is also made available After the new sulcus is created softened dental compound is added to the bite block and molded into the sulcus. The denture is used similarly the compound being added to extend the denture into the sulcus. The bite block immobilizes the skin graft the dental compound added to the denture is duplicated in acrylic thus forming the definitive prosthesis after the bite-block has served its purpose

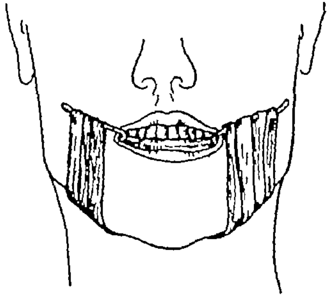

FIG 1036. Method of maintaining a skin graft in the lower buccal sulcus. The external bars of a Kingsley splint are fastened to a bandage passed under the chin.

1 The bite-block is maintained in position with circumferential wires and the jaw is immobilized by means of a Barton bandage.

2. An alternate but less preferable method is to construct a denture on the principle of the Kingsley splint with external bars extending from the corners of the mouth to the side of the face Dental compound is added and fitted into the newly incised sulcus the mold thus prepared is covered with a split thickness graft. In cases where the graft is transplanted to the maxilla, the bite block is anchored by connecting the external bars to a headgear If the graft is applied to the mandible, a firm bandage is passed under the chin from one bar to the other (Figs. 1036 and 1037)

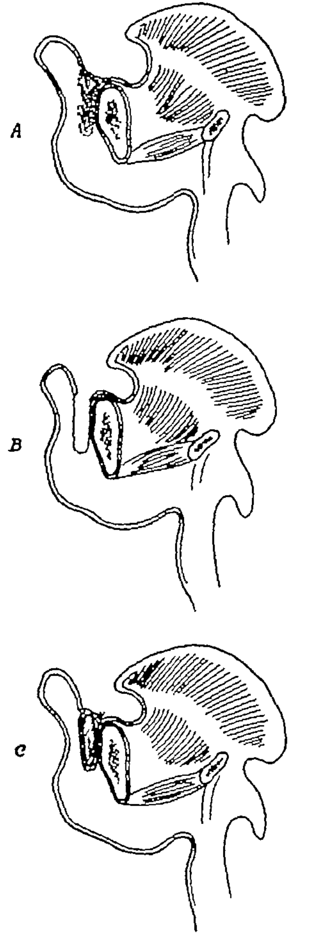

FIG 1035

A. Diagram showing the scar tissue to be removed or severed in establishing a buccal sulcus of moderate size.

B. The groove formed by the removal of the scar tissue.

C. Skin graft is wrapped around a compound mold and is maintained by sutures applied through the soft tissues.

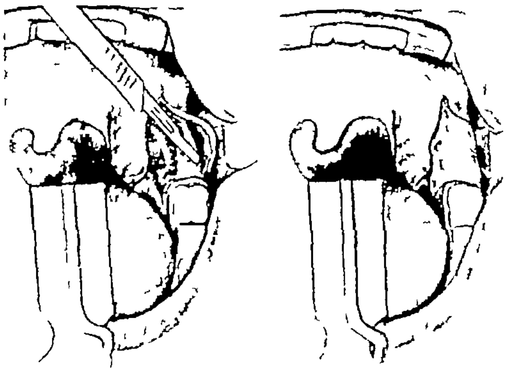

Fig 1039. (*Left*) Buccal mucosa freely undermined to cover resulting defect produced by shifting flap to restore pharynx (*Right*) Buccal mucosa sutured over defect.

wound (Fig 1038C) with mucosal tissue A flap is then advanced from the buccal mucosa to cover the secondary wound the incision being extended laterally into the cheek Undermining permits mobilization of the flap which is then sutured into the defect (Fig 1039) A similar operation is performed on the other side when indicated

STENOSIS OF THE NASOPHARYNX

Stenosis of the nasopharynx is usually characterized by dense scar tissue which may block the palato-nasopharyngeal space The nasopharyngeal airway is restricted or completely obstructed in such cases speech is nasal in quality and hearing may be impaired due to interference with the function of the openings of the Eustachian tubes. Cutting through the adhesions to open the nasopharynx does not achieve a permanent result even though plugs are used for a long period of time

To cover the raw area after release of the adhesions, tissue is provided by means of a free skin graft or a flap of mucosa from the buccal wall Attempts by the authors to transplant skin in these cases have resulted in failure although others have reported success with this method (Dorrance 1931 Figi 1917 Sanders, 1918) Good results have been obtained however with local flaps. The technique follows

The patient is placed in the Rose position affording a view of the palate oral pharynx and buccal cavity (Fig 1010) A rectangular flap of mucosa is raised on one side of the soft palate the base extending to the mucosa of the pharynx (Fig 1011) The scar tissue between the base of this flap and the palate is incised transversely to open the nasopharynx. The flap is then spread over the raw surface on the pharyngeal wall after release of the adhesions, and is retained by sutures and packing (Fig 1012)

A rectangular flap is rotated from the adjacent mucosa of the cheek to cover the raw surface on the palate (Fig 1012) created by elevating the first flap Flaps may be taken from either the lower or upper buccal wall.

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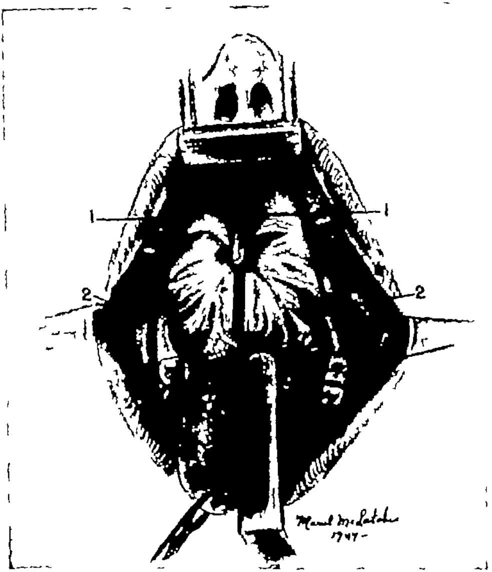


FIG 1040 Diagrammatic drawing of nasopharyngeal stenosis. 1 and 2 represent the flaps outlined for the repair

1 Mucosal flaps on the sides of the soft palate.

2. Flaps from the mucosa of the cheek to cover the raw area on the soft palate.

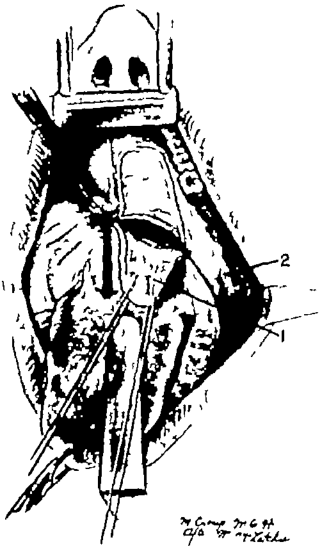


FIG. 1041 The flap from the soft palate (1) is raised. The diagram also shows the opening of the naso-pharynx by a transverse cut through the soft palate

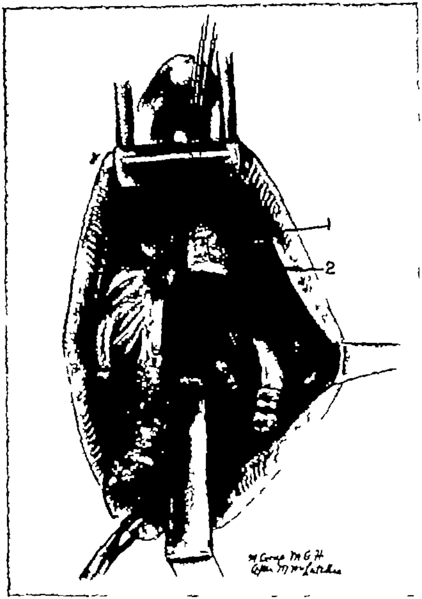


FIG. 1042. The mucosal flap (1) is spread over the raw surface of the posterior pharyngeal wall and held in position by sutures and postnasal packing. Dotted lines show the outline of the flap on the postpharyngeal wall. The cheek flap (2) is rotated to cover the raw area of the buccal surface of the soft palate.

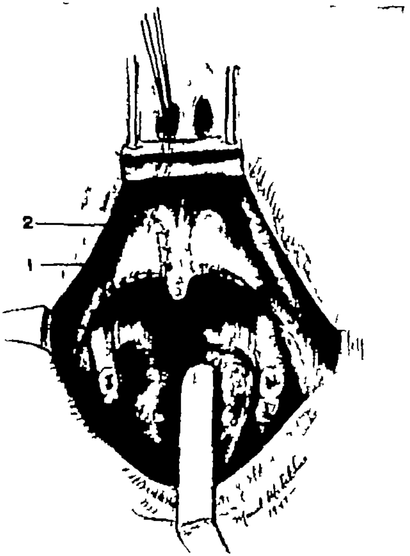


FIG 1043 Diagram showing the same procedure as in Figure 1042, applied to the opposite side

ryngeal packing is removed in three days, and antibiotics are administered. After the tissues have healed the operative procedure is repeated on the opposite side of the nasopharynx (Fig 1043)

ADHESIONS OF THE TONGUE

Minor injuries of the floor of the mouth which result in adhesions limiting the free movement of the tongue can be corrected by the V Y method.

Laceration of the floor of the mouth is sometimes associated with loss of the tip of the tongue (Fig 1011*A*) As healing occurs, the tip of the tongue adheres to the floor of the mouth thus impairing speech and deglutition

The deformity is corrected by making a horizontal incision through the adhesions under the tongue (Fig 1011*B*) the raw area remaining in the floor of the mouth and on the undersurface of the tongue is closed by approximating the borders, the horizontal incision line being changed to a vertical suture line (Fig 1011*C*) Care in making the incision is required to avoid injury to Wharton s duct or the ducts of the sublingual glands. If the tongue cannot be released by this method tranposition of a flap from an edentulous alveolar ridge may supply the necessary mucosa.

The following precautions are necessary when skin is transplanted to the floor of the mouth all the scars and avascular tissue are

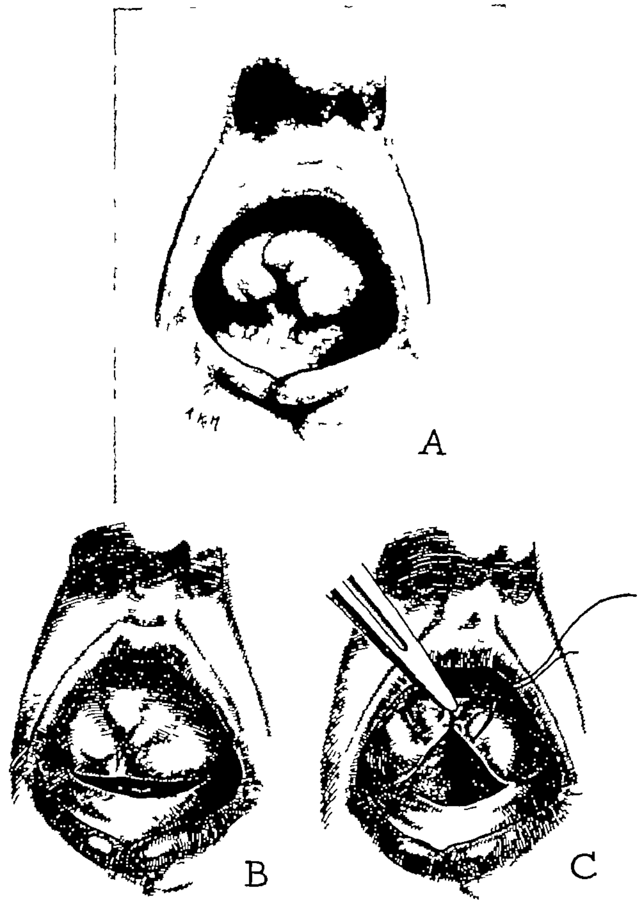


Fig 1044 Repair of scar adhesions binding the tongue to the floor of the mouth.

A. Such scars are frequent following severe maxillofacial injuries particularly following perforating wounds. otraction of the tongue is prevented and considerable impairment of speech and deglutition results.

B. Horizontal incision through adhesions under the tongue

C. The resulting raw area is closed by suturing the borders of the wound, thus changing the horizontal cision line to a vertical suture line.

excised, and the skin graft is immobilized by means of an appliance a sufficient amount of dental compound is added to the intraoral appliance in order to cover the raw area in the floor of the mouth Skin flaps from more distant areas, such as the neck, may be utilized to form a floor of the mouth in cases in which extensive reconstruction of the lower part of the face requires the use of distant flaps.

PERFORATIONS BETWEEN THE ORAL AND NASAL CAVITIES

Defects of the Hard Palate

Perforations resulting from trauma vary in size and may be located in any portion of the hard palate These defects should be closed by surgical methods if possible to improve speech and to prevent fluid and food particles from entering the nasal cavity

Closure of either large or small perforations depends for success on adequate vascularization of the surrounding mucoperiosteum Scar tissue adjacent to the edges of the defect is excised. Mucosal scars, unlike *those of the skin are difficult to distinguish* from the surrounding mucosa The tissue adjacent to the defect should be excised therefore to insure the removal of avascular scar tissue Closure in the majority of cases is accomplished by transposing flaps from the immediate neighborhood of the defect. Only in rare cases is the use of a distant flap indicated as a prosthetic obturator is a satisfactory and simple means of eliminating the palatal opening

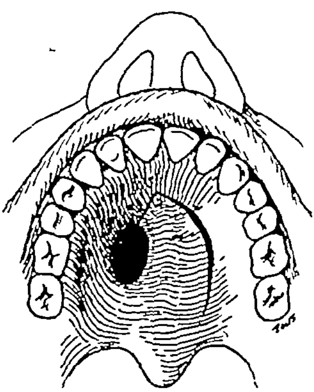


Fig 1016. Lateral perforation of the hard palate A flap is transposed from the unaffected side to close the defect The L-shaped outline of the flap indicated.

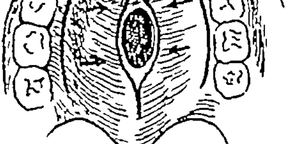


Fig. 1015 Median perforation of the hard palate Liberal excision of the scar surrounding the perforation is done and the mucoperiosteum is freely undermined through lateral incisions along the gingival margin.

Median Perforations of the Hard Palate

Anteroposterior incisions are made along the gingival margins of the teeth to repair such defects the mucoperiosteum is undermined freely and the borders are sutured (Fig 1015) mattress sutures are employed to obtain a wider surface of contact of the raw edges.

Lateral Perforations of the Hard Palate

The location of such a perforation influences the method of repair A defect in the *anterolateral section* of the palate is conveniently closed with a rectangular flap of

mucoperiosteum transposed from the unaffected side (Fig 1046)

An L-shaped incision is made from the border of the perforation forward toward the anterior teeth. This incision is continued laterally along the gingival margins of the teeth as far as the maxillary tuberosity if necessary The flap is raised, avoiding injury to the palatine vessels, and sutured to the borders of the perforation. The resulting triangular raw area is permitted to heal gradually Flaps of this or other types should be freed sufficiently to permit shifting of the tissue without tension.

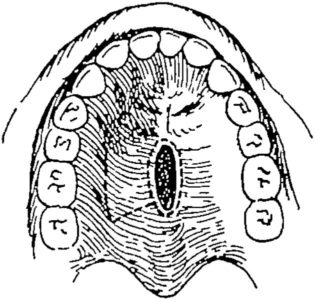
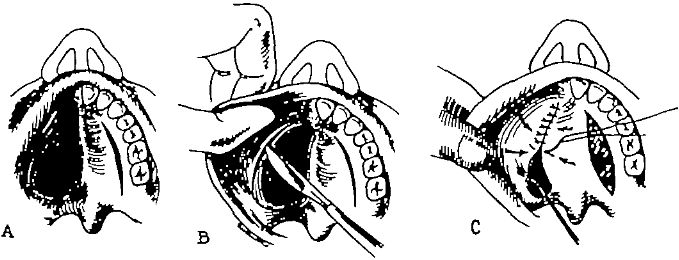


Fig 1047 A perforation in the posterior portion of the hard palate is conveniently closed by taking a flap from the side of the soft palate where there is an abundant amount of loose tissue.

A defect in the posterior portion of the hard palate is repaired with a large rectangular flap from the neighboring soft palatal tissue. An incision is carried from the lower part of the perforation, diagonally backward toward the maxillary tuberosity where a good deal of loose mucosa may be included in the flap and transferred to close the perforation The secondary defect is closed by approximation of the mucosal borders (Fig 1047)

Lateral Defects of the Hard Palate

Repair of defects of the side of the hard palate, involving the alveolar process, is accomplished by utilizing the mucoperiosteum of the unaffected side, and the mucosa of the cheek, depending upon the size of the perforation (Fig 1048) In such defects, the main flap should be taken from the mucosa of the cheek, for the tissue in this region is loose and can be transposed more easily The mucoperiosteum of the unaffected side of the palate is elevated by an incision along the gingival margins, extending from the anterior region back to the soft palate. The



A B C

Fig. 1048. Large opening of the lateral aspect of the palate resulting from the loss of half of the palate, including the alveolar process.

A. A bipedicled flap of mucoperiosteum from the unaffected side of the palate is raised.

B. Incision made to raise a mucosal flap from the cheek from which abundant tissue may be advanced.

C. The two flaps raised in A and B are advanced and sutured over the opening

bipedicled palatal flap is loosened sufficiently to cover at least one-half of the perforation. A second rectangular flap obtained from the mucosa of the cheek, is brought forward and sutured to the palatal flap. Because the mucosa of the cheek is elastic, it is possible to borrow large amounts of tissue closing the donor area completely. In the removal of buccal mucosa care must be taken to avoid injury to Stensen's duct.

Large Defects of the Anterior Part of the Hard Palate

Perforations of the anterior part of the palate involving the alveolar processes are closed by local flaps if the opening is of moderate size; neither palate nor cheek tissue however can be used as advantageously as in the correction of lateral defects. If one or both sides of the perforation are edentulous, however, local advancement flaps can be used effectively.

For the closure of large defects of the anterior part of the upper jaw the authors prefer to use prosthetic appliances. Distant flaps are available however if surgical closure of the perforation is considered advisable. The procedure consists of transferring a tubed skin flap from the nearest region, preferably the side of the neck or

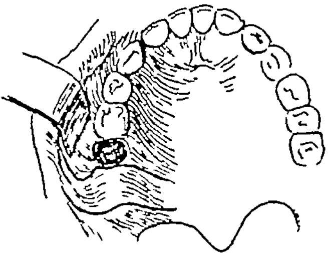


FIG. 1049. Bipedicled flap advanced from the region of the maxillary tuberosity to close the perforation over the crest of the alveolar ridge communicating with the maxillary sinus.

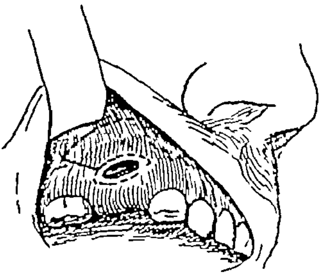


FIG. 1050. Perforation of the alveolar process. Flaps of liberal size can be secured from the buccal mucosa and the cheek to close such perforations.

using the wrist as a carrier of a more distant flap.

Small perforations through the crest or the side of the alveolus, leading into the maxillary sinus or nasal cavity are sometimes difficult to close. Failure may be explained by the fact that the avascular cicatricial tissue surrounding the defect is not completely excised. Chronic sinusitis may also be present and secretions may be draining while the perforation exists; when the defect is closed the accumulation of purulent secretions in the maxillary sinus may eventually cause separation of the suture line. In closing such perforations *it is necessary to* remove the antral mucosa and to create a window in the inferior meatus before closing the oroantral fistula.

Two methods can be employed for closing small perforations.

1. If the defect is over the crest of the alveolar ridge and one or both sides of the perforation are edentulous, a local bipedicled advancement flap can be used effectively (Fig. 1049). The resulting raw area is permitted to heal spontaneously.

2. Perforations through the alveolar process between two teeth and also at the buccal sulcus, are closed by borrowing a rectangu

lar or tongue-shaped flap from the mucosa of the lateral portion of the buccal alveolar process, or from the cheek, the flap is brought forward and sutured along the borders of the perforation (Fig 1050)

Flaps can be borrowed from the palate to cover perforations of the alveolar ridge. Palatal mucosa is not elastic, however and does not lend itself to twisting or shifting except in straight lines, whereas the mucosa of the cheek is more elastic and can be utilized more effectively

26

TRAUMATIC DISTURBANCES OF THE TEMPOROMANDIBULAR JOINT

The temporomandibular joint may be injured in fractures of the body of the mandible or by a blow or a fall on the chin

Intracapsular hemorrhage and edema of the meniscus may cause acute pain in the joint and limitation of mandibular movement and may also produce disturbances of the dental occlusion.

Following subsidence of the pain swelling and limitation of motion, persistent symptoms may reveal the presence of chronic injury in the joint due to damage to the meniscus. Movements of the jaw are limited and crepitation may be felt with the tip of the finger and heard by means of a stethescope (Shapiro 1951) placed over the joint finger pressure directly over the joint causes pain

The injury can be severe enough to produce dislocation of the meniscus. After the acute symptoms have subsided, the patient becomes annoyed by the constant clicking sound which accompanies anteroposterior excursions of the jaw and may also become aware of an intermittent blocking of the joint which interferes with mastication or mandibular movements.

When the articular disk is torn loose from the surrounding structures, it may be pulled forward and medially by the contraction of external pterygoid muscle fibers, and is retained in a forward position between the condyle and the articular tubercle An open bite deformity is observed in these cases for the head of the condyle is displaced upward into the glenoid fossa. Fractures involving the temporomandibular joint fractures of the glenoid fossa and tympanic plate and tearing of the meniscus are particularly serious in children because they are usually followed by ankylosis. Changes in the joint may also occur following fractures of the condylar neck due to the abnormal relationship of the condyle to the glenoid cavity caused by malunion.

RECURRENT DISLOCATION OF THE JAW

Recurrent and habitual dislocation of the temporomandibular joint and chronic subluxation with clicking are usually due to looseness of the capsule and ligaments, and also to displacement of the meniscus. The surgical treatment of such a condition consists of exposing the capsule shortening it by excision of tissue or by plicating and suturing the capsule When the meniscus is damaged or dislocated the capsule is incised and the meniscus removed The capsule is then shortened by excision or plication

TEMPOROMANDIBULAR ANKYLOSIS

Ankylosis of the jaw may be classified into two groups (1) the intra-articular in which the ankylosing factors lie within the joint and (2) the extra articular caused by pathologic conditions outside the joint Both types are defined in degree as complete or partial and unilateral or bilateral

Etiology

Intra Articular Ankylosis

Trauma or disease are the predisposing causes of chronic intra articular ankylosis of the temporomandibular joint. Infection may have occurred within the joint in the neighborhood of the joint, in the mandible, the middle ear or the oral cavity The predisposing traumatic agent is usually external violence which is transmitted to the joint through the mandible. The end results of disease or injury are scars and joint destruction. Because of the slow development of ankylosis, direct connection between cause and effect is often unknown to the patient or to the family

Injury is the most important single cause of ankylosis. A history of injury such as a blow on the jaw a coasting accident, fall automobile accident or jaw fracture is often reported by the patient.

Extra Articular Ankylosis

Chronic extra-articular ankylosis may be due to a pathological lesion or factors involving the soft tissues surrounding the lower jaw such as scars about the muscles of the jaws or scars of the mucosa skin or subcutaneous tissues of the face. These extra capsular lesions are commonly the result of injury such as gunshot wounds, where extensive loss of tissue has occurred. Other extracapsular conditions resulting in stiffness of the temporomandibular joint are fracture, cicatricial adhesion of the coronoid process to the zygomatic arch and depressed fracture of the zygoma with pressure against the coronoid process

The authors have seen a number of conditions in which the ramus of the mandible has been fused with the infratemporal surface of the maxilla. In such cases, diagnosis is the important factor for function can only be restored by separation of the bony mass.

Surgical Pathology

A study of the pathology of intra-articular ankylosis usually reveals progressive degrees of joint destruction (Murphy 1914 Lyons, 1917) The earliest changes occur in the cartilaginous and capsular structures. The meniscus is often completely destroyed quite early the joint space is narrowed by destruction and changes occur in the articular cartilaginous surfaces. The joint capsule shrinks and adheres to the adjacent structures. Fibrous bands develop and thicken until most of the joint space is obliterated. The fibrous bands and the scarred joint surfaces may become calcified. The mandibular condyle develops proliferative bony changes, becoming thick and massive. The mandibular fossa flattens and becomes shallow Formation of a true osteoma and exostosis may occur The entire joint area finally loses it normal landmarks in a mass of bony union.

It is important to remember that the opposite joint remains unaffected even in unilateral ankylosis of many years duration. Bilateral ankylosis is an infrequent condition, usually caused by rheumatoid arthritis or injury

The pathological process varies in each case of extra articular ankylosis. The oral mucosa may be covered with thick scar tissue. Fibrosis or injury to the muscles of mastication principally the masseter and pterygoids may prevent jaw function The site of the scar tissue cannot always be determined preoperatively and must remain a matter of conjecture until disclosed at the time of operation

Examination and Diagnosis

Clinical Examination

Patients with ankylosis of the mandible, even those with complete inability to open the mouth suffer but slight difficulty with speech. Dental deterioration results from poor mouth hygiene and the impossibility of administrating dental care.

Intra-articular and extra articular ankylosis can be differentiated when the patient is asked to thrust the jaw forward. The joint cavities are not affected in the extra-articu

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TRAUMATIC DISTURBANCES OF THE TEMPOROMANDIBULAR JOINT

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Intra articular and extra articular ankylosis can be differentiated when the patient is asked to thrust the jaw forward. The joint cavities are not affected in the extra-articu

A B

Fig 1051

A. Photograph of patient with unilateral ankylosis of the right temporomandibular joint. When the patient opens his mouth, the jaw deviates toward the affected side because of the absence of forward motion in the ankylosed joint. (Loss of external pterygoid muscle function) Note deviation of the chin toward the right. The lines on the lip demonstrate the deviation from the mid line.

B. After operation the patient can open the mouth the right side still moves like a hinge joint, while the normal side moves forward.

lar lesions the jaw gliding forward equally on both sides, with no deviation to either side Forward motion occurs only on the unaffected side in intra articular ankylosis and a slight deviation of the chin toward the affected side can be observed In unilateral intra articular ankylosis a slight deviation of the chin toward the affected side can be observed (Fig 1051). In bilateral intra articular ankylosis, no forward thrust is possible although slight opening may be achieved even with complete bony ankylosis because of the elasticity of the mandible.

Examination and history are of value in extra-articular ankylosis to aid in determining the impaired side The patient may state that the right or left side "catches," thus affording an additional clue.

Intra articular ankylosis, occurring before the age of twelve years, and present for an appreciable length of time results in varying degrees of deformity Underdevelopment of the mandible is evident when the ankylosis is complete In bilateral ankylosis the underdevelopment is generally symmetrical (see Figs. 951 and 913) Assymmetry is pronounced when only one side is affected the chin deviates to the affected side because of *diminished growth* of the mandible on that side (Fig 1052) Two explanations are offered for this hypoplasia the first is that the trauma directly affects the growth center in the condyle the second is lack of proper function. The latter theory is disproved however by the fact that in bony ankylosis the unaffected side grows almost to normal size although it is largely deprived of its function. Interference with normal growth centers is the most important factor in underdevelopment of the jaw since destructive and bony changes in the region of the condyle of the mandible or involving the ascending ramus from any cause commonly result in hypoplasia of the mandible on the affected side

Secondary pathological changes related to function and facial contour are of importance in children The deformity varies

A B

FIG 1052

A. Photograph of patient (aged five and one-half years) who had been injured in an automobile accident two years previously suffering a fractured jaw as well as multiple arm and leg injuries. When seen at age of five and one-half years the patient had bony ankylosis of the left temporomandibular joint but very slight asymmetry of the face was noted. Condylectomy was performed.

B. Photograph of patient (aged eleven and one-half years) at which time he was able to open the mouth, but marked retrusion of the lower jaw had developed with the chin deviated to the left. The distance between the tragus of the right ear and the median line of the chin was 12.5 cm while on the left side the distance was 11 cm. The teeth were quite irregular

directly with the age onset and degree of ankylosis (Fig 1052)

Roentgenographic Examination

Roentgenographic studies of both joints are of assistance in deciding upon the proper surgical treatment. The articular lesion may usually be seen distinctly and bony changes and overgrowth are apparent. In intraarticular ankylosis which has occurred early shortening of the ramus is noticeable. A deepened preangular notch on the affected side of the body of the mandible is noted in these cases (Figs 1053 and 1054)

Treatment of Ankylosis

Intra-articular Ankylosis

The treatment of intra articular ankylosis of the temporomandibular joint is a surgical problem The pathological changes in the joint are such that mechanical manipulation is of no value Even if the jaw is only partially ankylosed and a degree of motion remains, repeated attempts to increase the range of motion with mechanical devices are doomed to failure. There is no valid reason to delay surgical intervention because of the age of the patient. Surgery for ankylosis has been performed by the authors in children as young as five years surgery at an early age enables the patient to masticate earlier

In bilateral ankylosis no attempt should be made to operate on both sides simultaneously If both joints are treated in the same operating session the muscles of mastication pull the mandible upward and the bones are likely to reunite in malposition.

ANESTHESIA. Difficulties are encountered in the anesthetic management of these cases careful preparation of the patient prevents undesirable complications Vomiting is particularly dangerous and a suction apparatus should be available during the operation

A B

Fig 1051

A. Photograph of patient with unilateral ankylosis of the right temporomandibular joint. When the patient opens his mouth, the jaw deviates toward the affected side because of the absence of forward motion in the ankylosed joint (Loss of external pterygoid muscle function) Note deviation of the chin toward the right. The lines on the lip demonstrate the deviation from the mid line

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FIG 1054 Laminograph of complete bony ankylosis of the temporomandibular joint. The joint is completely obliterated and bony continuity extends from the mandible to the temporal bone.

and during recovery from the anesthesia A tracheotomy set should be held in readiness as an additional precaution although the authors have never experienced the need for such a procedure.

Maintaining the airway is an important consideration since it is difficult to reach the tongue in order to draw it forward. Intratracheal anesthesia administered through a nasal tube introduced by blind intubation is the most effective method although technical difficulties may be encountered in its execution Before the anesthetic is administered a heavy rubber tube about 1 cm in diameter may be inserted through open spaces between the teeth or through gaps created by loss of teeth. The tube may be passed over the tongue through the oropharynx to provide an additional airway

OPERATIVE TECHNIQUE. Several approaches to the temporomandibular joint and a variety of incisions have been described. Whatever the approach to the joint, it is important that the bone should be sectioned either through the neck of the condyle or completely across the ramus at a sufficiently high level to provide good postoperative function

Arthroplasty of the temporomandibular joint involves surgical hazards which include the danger of injury to the facial nerve, and hemorrhage due to the proximity of the internal maxillary artery

The preferred line of incision lies directly

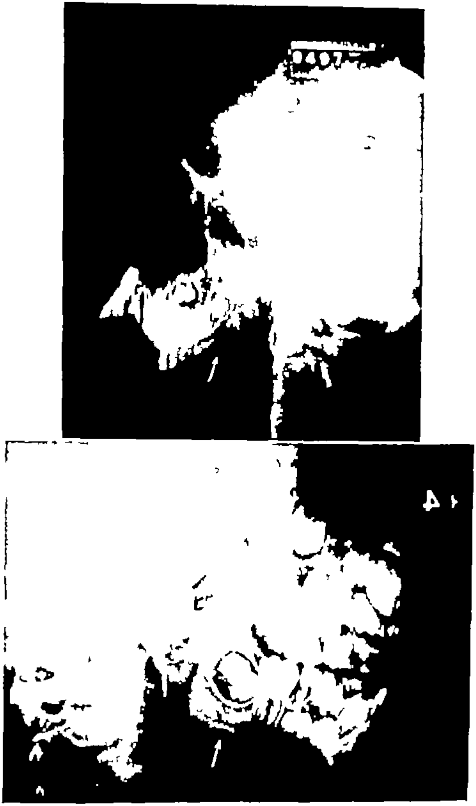
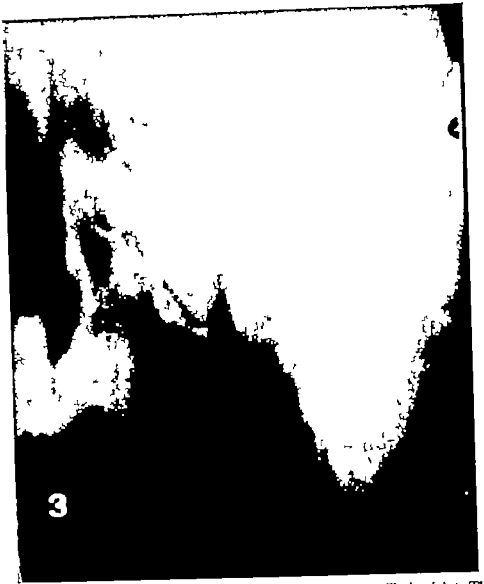


Fig. 1033 Roentgenograms showing the deep preangular notch on the body of the mandible present on the affected side in temporomandibular ankylosis. Note the continuity of the ramus with the temporal bone and the thickness of the bone in the articular region.



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The preferred line of incision lies directly

in front of the auricle but is never extended downward to a level which may endanger sectioning the trunk of the facial nerve Although the branches of the facial nerve supplying the orbicularis oculi and frontalis muscles are well anterior to the operative field they may be stretched thus resulting in temporary paralysis. To guard against injury to blood vessels surgical burrs or the Gigli saw for bone resection are discarded in favor of up-cutting bone instruments, rongeurs and at times a chisel all employed under direct vision.

An external incision below the border of the angle of the mandible affords an excellent avenue for exploration of the ascending ramus and the masseteric and pterygoid regions and is sometimes used in conjunction with the usual preauricular approach for diagnostic purposes especially in cases of extra articular ankylosis.

For intra articular ankylosis a vertical skin incision is made just anterior to the tragus and extended downward as far as the lobe of the ear (Fig 1055*A*) The superficial temporal vessels are identified and either ligated or retracted. The temporal fascia and zygomatic process of the temporal bone are exposed the latter serving as a landmark to define the anterior limits of the joint (Fig 1055*B*). The area of the joint and the head of the mandibular condyle are located just below and deep to the zygomatic arch. The normal landmarks of the joint are usually obliterated and replaced by a continuous mass of bone between the ramus and the zygomatic process of the temporal bone. An incision is made through the periosteum of

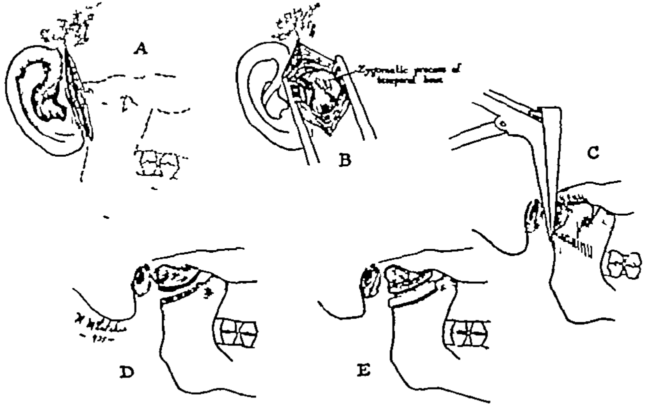

Fig 1055. Diagram showing the various steps in the operative procedure for arthroplasty of the temporomandibular joint.

A. Incision line.
B. Exposure of the operative field.
C. Position of the back biting forceps at the initial cutting
D The line through which definite section of the bone is removed.
E. A sufficient amount of fascia is inserted between the cut ends of the bone to eliminate dead space

(From V H Kazanjian, Surg Gynec & Obst 67 333 1938)

the zygomatic area and the region of the condyle is exposed subperiosteally The exposure is extended posteriorly until the upper posterior border of the ramus below the neck of the condyle is well-defined and freed for a distance of 2 cm. Examination of the joint may reveal fibrous changes and scarring· the head of the condyle may then be dissected away to enlarge the gap between the bony components.

The forward resection of a segment of the condyle is then initiated. The resection is extended toward the sigmoid notch with an up-cutting Kerrison punch forceps (Fig 1055C) By keeping within the periosteum and performing cutting procedures under direct vision the internal maxillary artery located just medially to the neck of the condyle is not endangered. A half-curved gouge is used when the condyle is found to be thick. The superficial part of the resection is accomplished with the gouge biting instruments are reserved for the deeper portions. The segment of bone removed should be at least 5 to 10 mm in width.

Resection includes the entire width of the ramus in cases which disclose a shallow sigmoid notch or when the coronoid process is involved in the bony union or interferes in any way with the function of the mandible.

No unusual instruments for retraction are necessary for the above procedures a certain amount of traction on the tissues is necessary to keep the field of operation exposed the focused light from a head mirror or head lamp is necessary for proper illumination

Hemorrhage is not severe during the operation and hemostasis is usually confined to the control of venous oozing Excessive bleeding may be controlled by gauze packing A strip of fascia lata, approximately 5 cm. long and 2.5 cm. wide is inserted into the area from which the bony segment is removed. An attempt is made to tuck the edges of the transplant under the bone ends, but it is not sutured to the surrounding structures. The fascia not only serves to cover the bone ends but also prevents immediate and postoperative hematoma by filling the dead space between the bony stumps (Fig. 1055D C) A long fascial strip may be removed through a small incision by means of the fascial stripper (see Fig 472 Chapter 19)

The wound is closed and a pressure dressing is applied. The patient s mouth receives no special attention or care at this point, no mouth gag or other apparatus being required

POSTOPERATIVE CARE. The jaw is kept entirely at rest for one week. A liquid diet is prescribed and the patient is cautioned against chewing or moving the mandible for several days The period of rest not only accelerates the healing process but insures viability of the transplant and thus helps to prevent a recurrence of the ankylosis.

Extra-articular Ankylosis

Treatment is dictated by the extent and location of scars involving muscles of mastication, oral mucosa or the coronoid process of the mandible. After repair of lacerations of the soft tissues of the face and oral cavity loss of a degree of elasticity in the repaired tissues limits the excursion of the mandible. In the majority of such cases, physical therapy in the form of heat and massage and mechanical exercisers (See Figs. 196 to 198 Chapter 6) are of assistance.

Scars which bind the coronoid process usually extend from a penetrating wound. The ankylosed area is approached through the scar area of the skin in such cases it may be necessary to excise the entire coronoid process. If no external wound is present, the coronoid process is exposed through a vertical incision in front of the auricle (Fig. 1055A) or through the oral cavity

Complete excision of the cicatricial tissue and replacement with healthy skin covering is indicated when dense scars resulting from soft tissue loss bind the upper and lower jaws together Skin grafting is em

ployed when the loss of normal tissue is limited to the mucosa of the cheek. The use of a pedicled flap is indicated when other structures in addition to mucosa must be restored (see Fig. 1021 Chapter 24)

Depressed fractures of the zygomatic arch, which result in limited motion of the temporomandibular joint may be elevated by extra-oral manipulation through the temporal route after osteotomy

27

FACIAL PARALYSIS

Facial disfigurement due to facial paralysis is noticeable not only because of the expressionless immobility of one side of the face, but because the muscles of the unaffected side, in the absence of active homolateral antagonists pull the paralyzed side of the face to one side the distortion is accentuated when smiling laughing or whistling When an attempt is made to close the eyes closure of the eyelids occurs only on the normal side. In paralysis of long standing, atrophy of the musculature results in a sagging of the soft tissues of the face the lower eyelid droops downward in ectropion and the cheek and angle of the mouth sag (Fig 1056) Chronic conjunctivitis and epiphora results from lack of protection of the eyeball the patient is unable to control the flow of saliva and also experiences difficulty in speaking

Complete unilateral paralysis occurs if the main trunk of the facial nerve is severed. Partial facial paralysis results from the sectioning of one or a number of the terminal branches of the facial nerve but is usually only a temporary condition because of regeneration and return of function through anastomoses between terminal filaments of the nerve.

ANATOMIC CONSIDERATIONS

The facial nerve originates in the facial nucleus within the medulla. The internal genu is formed by the course of the nerve over the nucleus of the sixth cranial nerve The nerve emerges at the posterior border of the pons and extends anterolaterally entering the internal auditory meatus and penetrating the petrous bone. In the region of the geniculate ganglion the facial nerve bends its course at the superior genu and enters the middle ear through the angle between the vestibule and the superior semicircular canal It extends behind the oval window altering its course again at the inferior genu passing downward in the Fallopian canal to the stylomastoid foramen. It then turns anteriorly into the substance of the parotid gland where it forms a plexus of nerves (Fig 1057) the terminal branches are distributed to the muscles of facial expression (see Fig 13 Chapter 1)

The facial nerve is a mixed nerve. Motor fibers from the motor nucleus supply the stapedius muscle of the middle ear the superficial musculature of the face and scalp the platysma the posterior belly of the digastric and the stylohyoid muscles (Fig 1057) Parasympathetic fibers from the superior salivary nucleus pass by way of the nervus intermedius to the glands of the pharynx, palate nasal cavity and paranasal sinuses via the greater superficial petrosal nerve and the sphenopalatine ganglion These parasympathetic fibers also supply secretory motor impulses to the submaxillary and sublingual glands through the chorda tympani and lingual nerves and the submaxillary ganglion.

Sensory fibers from unipolar cells in the geniculate ganglion receive peripheral fibers which conduct taste sensation from the

A

B

C

D

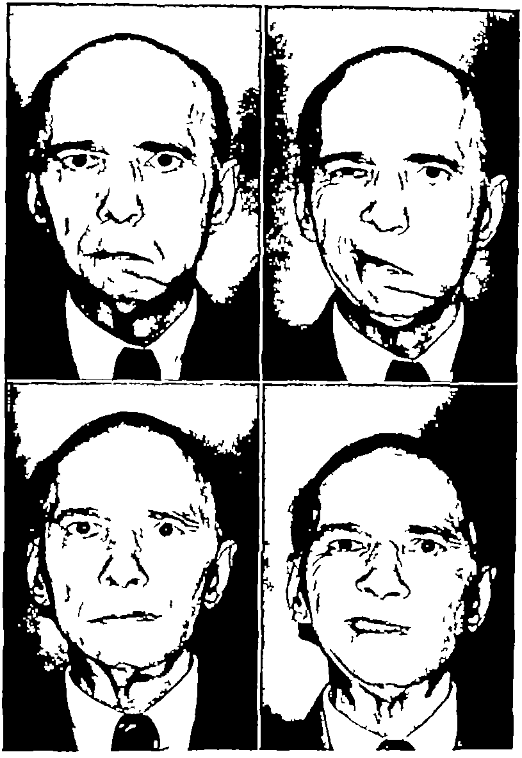

Fig 10.6

A Facial paralysis of many years duration The paralyzed left side of the face is sagging

B Deformity accentuated when patient smiles The active muscles on the right side of the face in the absence of normal antagonists on the left side pull over the paralyzed side of the face

C Appearance of the patient after fascia lata suspension

D As a result of the fascial suspension the paralyzed left side of the face is prevented from being pulled over to the right

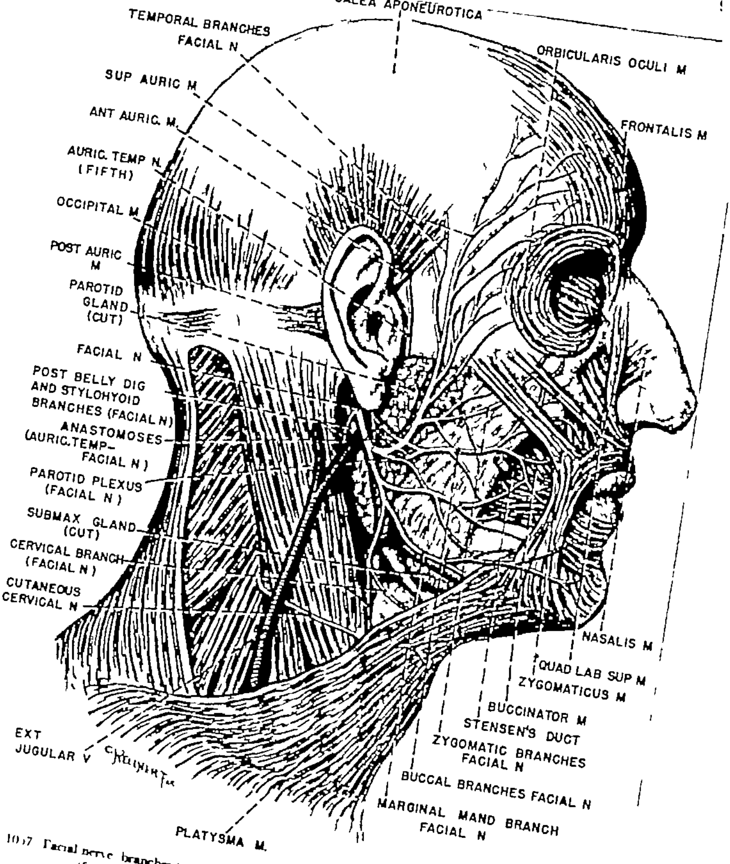

Fig 1057 Facial nerve branches to the muscles of facial expression (redrawn and modified after Corning) (from H H Shapiro, *Maxillofacial Anatomy* J B. Lippincott Co 1954)

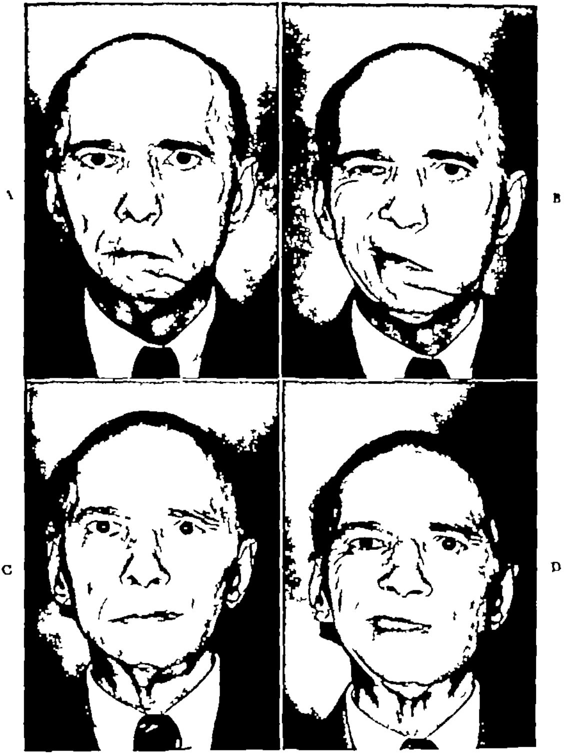

FIG. 1036

A. Facial paralysis of many years duration. The paralyzed left side of the face is sagging.

B. Deformity accentuated when patient smiles. The active muscles on the right side of the face in the absence of normal antagonists on the left side pull over the paralyzed side of the face.

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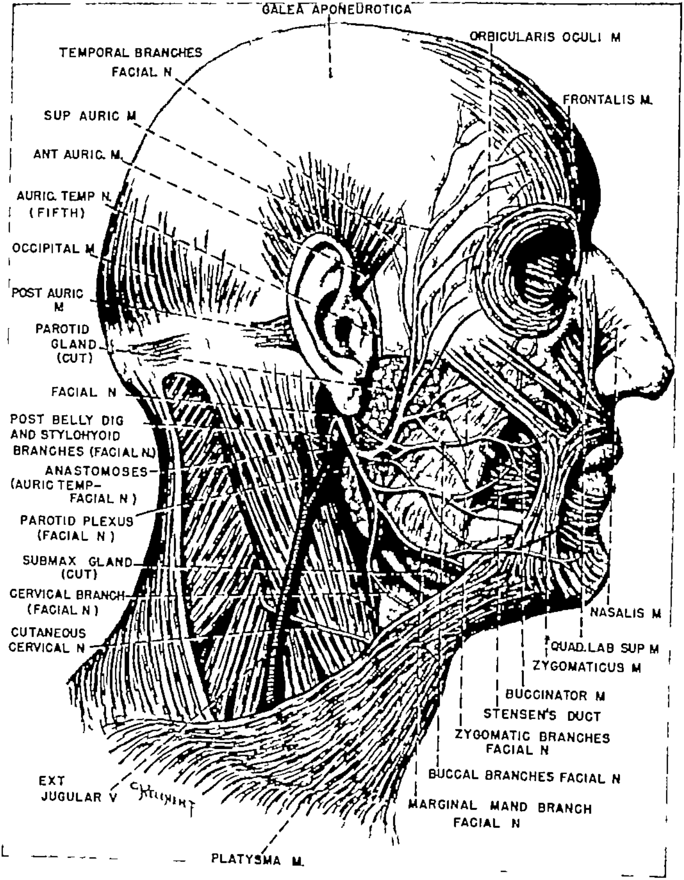
D. As a result of the facial suspension the paralyzed left side of the face is prevented from being pulled over to the right.



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anterior two thirds of the tongue by way of the lingual and chorda tympani nerves and sensation from the parotid gland via the otic ganglion and geniculotympanic nerves

The facial nerve after exiting from the stylomastoid foramen supplies branches to the posterior auricular stylohyoid and posterior digastric muscles. The nerve then enters the parotid gland forming a plexus of nerves from which five main branches temporal zygomatic, buccal mandibular and cervical spread to the superficial muscles of the face (Fig 1057) These are connected by anastomotic branches with the exception of the mandibular which receives no anastomotic branch This anatomic fact accounts for the resulting paralysis in the corresponding half of the lower lip when the mandibular branch is sectioned. The temporal branch is the longest of the branches of the facial nerve probably accounting for the lack of regeneration of this branch following repair of the nerve

The buccal branch can be located because of its close proximity to Stensen s duct (Fig 1057) the duct crosses the masseter muscle at a level corresponding to a line which passes from the base of the lobe of the ear to the mid level of the upper lip. The mandibular branch can be located through its relationship with the external maxillary artery and anterior facial vein along the mandibular border it also has an important relationship with the posterior facial vein which joins with the anterior facial and posterior auricular vein to form the common facial vein emerging from the lower pole of the parotid gland The mandibular and cervical branches of the facial nerve cross the lateral surface of the posterior facial vein (Fig 1057) and can thus be located by tracing the vein superiorly (Lathrop 1953)

Muscles Innervated by the Facial Nerve

The facial innervation accounts for the following muscular functions (1) Closure of the eyes (orbicularis oculi muscle and the evacuation of tears by contr[illegible] of the lacrimal sac (Horner s muscle) (2) Opening and closing the naris (the nasal musculature) Charles Bell (1821) referred to the facial nerve as the respiratory nerve of the face (3) Mobility of the lips and cheeks structures which play a role in mastication and deglutition a flaccid cheek has difficulty in controlling food particularly liquids pronunication of labial consonants is also hampered thus affecting communication through speech sucking blowing and whistling are not possible in most cases of facial paralysis (4) The mobility of the superficial facial musculature is a means of communicating emotions Darwin (1872) wrote The power of communication between members of the same tribe by means of language has been of paramount importance in the development of man and the force of language is much aided by the expressive movements of the face and body

Duchenne de Boulogne (1862) made a number of observations concerning the function of the muscles of facial expression (1) The contraction of one muscle alone can achieve a complete expression The contraction of the frontalis muscle for example expresses attention when this muscle alone contracts, the entire expression of the face being modified by the contraction of but one muscle (2) A muscle can require the contraction of neighboring muscles to give the desired facial expression The quadratus labii superioris muscle produces an artificial smile but when it contracts concomitantly with the lower part of the orbicularis oculi muscle the smile acquires an expression of benevolence (3) Other muscles which are in themselves completely inexpressive add to the expression when they contract simultaneously An example is the platysma muscle when it contracts alone it causes wrinkling of the skin of the neck an expression of torture and of fear is produced when it contracts concomitantly with the frontalis and co[illegible] muscles and the mouth is open

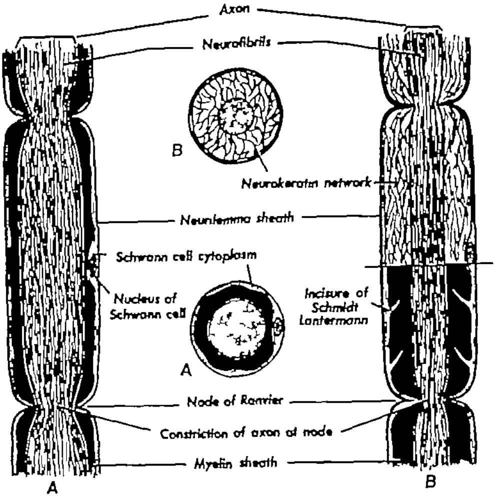

Fig 1058 Schematic drawing of medullated nerve fibers

A. Longitudinal section of a single Internode, showing axon and its sheaths. The relative diameters of axon and myelin sheath are based on de Renyi s studies of the living nerve fiber

B. Cross section at the level of the Schwann cell nucleus in A.

C. Longitudinal section of an internode showing shrunken axon

D Cross section of fiber shown in C.

(from Bailey's Histology Ed. 14 The Williams & Wilkins Co., 1958)

The Structure of a Nerve

The nervous system central and peripheral is composed of the following elements (1) Neurons which may be defined as the nerve cells with all their processes these may extend for considerable distances away from the cells for the specific purpose of conduction (2) The interstitial tissue of the nervous system represented in peripheral nerve fibers by the neurilemma cells (3) Connective tissue which forms the sheaths enveloping the peripheral nerves. The neurons and interstitial tissue are of ectodermal origin connective tissue is of mesodermal origin

The axon is the nerve cell process which conducts impulses from the cell body It consists of neurofibrillae which are embedded in the undifferentiated protoplasm known as axioplasm. The nerve fiber consists of the axon and the sheath Figure 1058 illustrates the structure of a nerve.

NERVE DEGENERATION

The laws of Waller established the fundamentals of nerve degeneration (1) An axis-cylinder degenerates when separated from its trophic center (2) The direction of degeneration is independent of nerve conduction

Degeneration is constant in the distal portion of the nerve and is known as Wa

degeneration Degeneration is complete about the fourteenth day and the nerve is represented only by Schwann tubes emptied of axons and of the myelin sheaths. After degeneration the empty tubes are filled by the protoplasm of the Schwann cells re habitation of the tubules is possible during this period The Schwann tubes collapse later and are obliterated thus constituting an obstacle to nerve repair

Effect of Nerve Degeneration on Muscle

A nerve cell with its axon is associated with a certain number of muscular fibers, together these constitute a motor unit. The axons lose their sheaths of myelin dividing when they reach the motor plates.

The muscle loses its compact appearance during the first three months following nerve section and the histological appear ance is one of an increase in the number of nuclei dilation of vessels and perivascular infiltration indicative of circulatory stasis. The muscle fibers shrink after the third month the disks become discolored and some of the muscle tissue is replaced by fatty and fibrous tissue The motor plates cannot be found after the ninth month and the ends of the sheaths are invaded by histiocytes. These alterations are characteristic of atrophy A period of many years elapses however before signs of actual degeneration appear in the muscle fibers. These phenom ena have been studied by Bowden and Gut mann (1945) The prognosis is poor if re innervation of the muscle does not occur during the first year Regeneration cannot be expected after the third year

Muscles deprived of their nerve supply become flaccid and undergo progressive at rophy Fibrous tissue proliferates as the mus cle fibers shrink obliterating the terminal Schwann tubes and motor end plates. The muscle fibers may regain their tone if re innervation occurs before fibrosis is com plete the greater the fibrosis however the poorer the prognosis.

Fibrosis following denervation occurs rapidly in the delicate musculature of the face The superficial muscles of the facial ex pression lack well-defined muscle fascia they are inserted directly into the dermis of the skin without the intermediary of subcutane ous tissue Overstretching the tissues is due to gravity and to the pull of the muscles on the unaffected side

Nerve Regeneration

The proximal end of the nerve is the source of new elements which attempt to re habitate the peripheral segment an initial phase of growth is followed by a subsequent phase of maturation

Phase of Growth

The initial phase begins by proliferation of cellular chains of Schwann cells which have migrated from the sectioned end of the central segment this early proliferating tis sue has the character of a syncitium Maxi mum growth occurs between the fifteenth and twentieth day When the newly formed fibers have met the Schwann tubules a num ber of them penetrate one single tube (Holmes and Young 1943) Only one how ever increases in size and becomes sur rounded by myelin the others disappear Myelin is responsible for functional repair

Phase of Maturation

The newly formed axons grow downward into the Schwann tubules increase in size and become surrounded by myelin. The Schwann cells form new sheaths which even tually surround each fiber of myelin

Experimental studies of mixed nerves in dicate that some fibers lose their direction and penetrate sheaths previously occupied by sensory fibers. The proportion of fibers that reach the distal segment is only about 60 per cent of the fibers of the central seg ment (Sanders 1942 Sanders and Young, 1945) These findings are less optimistic than the evaluation of Tickle (1945) for whom the clinical repair following nerve grafting for facial paralysis attained about 90 per cent of

the former state in some cases Regeneration of an essentially motor nerve such as the facial nerve is much higher than in mixed nerves with a high proportion of sensory fibers. The rapidity of regeneration varies according to the nerve, from 1 to 7 mm per day regeneration is more rapid in young individuals than in adults.

The activity of the Schwann cells is at its height about two or three weeks after section and persists until about the one hundredth day Myelinization and maturation of new axons become defective later the Schwann tubes shrink and re-entry of axons into the peripheral stump is more difficult recovery of function becomes imperfect or impossible (Gutmann and Young, 1944) Return of function cannot occur after the muscle atrophies After section of the nerve the period of 21 days proposed by Collier (1949) appears to be the optimum time for repair of the nerve In a patient with a sectioned facial nerve in whom the clinical condition may not permit immediate repair suture of the nerve can still be undertaken successfully about the end of the third week postponement of the operation diminishes the chances of successful repair

Degenerative and Non-degenerative Lesions

An appreciation of the fundamental distinction between degenerative and non-degenerative lesions is an important consideration when dealing with lesions of the facial nerve.

Conduction of the nerve impulse may be arrested temporarily by a lesion which affects the myelin sheath without leading to axon degeneration paralysis may be complete but not accompanied by wasting of the muscles and electrical reactions are usually unchanged no fibrillation is detected by electromyography This state of block may be present for weeks without interfering with complete recovery

Pressure on the nerve trunk may result in occlusion of the blood vessels of the nerve sheath the ischemia affecting the myelin sheath and sparing the axons and Schwann cells Pressure ischemia of the facial nerve in the Fallopian canal may be due to operative injury in mastoid surgery or to fracture. If pressure is continued, the interruption of circulation leads to edema above and below the site of compression A degenerative lesion involving the axons and the Schwann cells may result unless compression is relieved

Interruption of the axons with preservation of the supporting elements is usually followed by recovery because the axons can grow along old paths recovery however is not perfect. Complete section of the nerve is not the only cause which prevents spontaneous regeneration for intraneural fibrosis may destroy the Schwann cells and interrupt the continuity of the neurilemma tubes.

A degree of degeneration occurs in the central segment after section of the nerve, but each axon sends out numerous sprouts which grow outward and backward, forming a neuroma in the surrounding scar tissue.

ETIOLOGY

Paralysis of the facial nerve is a major cause of facial disfigurement. In the past damage to this nerve occurred most frequently in the course of mastoid surgery but this complication is no longer a common-place condition for mastoid surgery is performed less frequently than in former years

Bell's palsy or idiopathic facial paralysis appears as a sudden loss of facial muscle function It may be due to exposure, to cold or to a viral infection such as *herpetic neuritis*, as in Ramsay Hunt's syndrome. It is now believed that *ischemia causes* edema and swelling of the nerve, paralysis resulting when the nerve cannot expand in the bony Fallopian canal No satisfactory theory has been offered, however for the cause of the ischemia

Facial paralysis, as a result of trauma to the skull and face is rarely encountered

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When it does occur the nerve is usually involved in transverse fractures of the petrous bone and is injured in the region of the internal auditory meatus. Fractures involving the middle ear such as those which occur in longitudinal fractures of the petrous bone, usually cause injury of the nerve in the Fallopian canal

Soft tissue injuries of the face may affect the nerve in any part of its course from its exit from the cranium to its distribution from the plexus in the parotid gland. Because of numerous anastomoses after the division of the main trunk and also due to the fact that facial muscles, such as the quadratus labii superioris and zygomaticus muscles receive facial nerve branches posteriorly through and through injuries of the cheeks and lips rarely result in any appreciable paralysis of these muscles. An exception to this rule however is the mandibular branch of the nerve which extends along the lower border of the body of the mandible and divides into terminal filaments below the angle of the mouth.

When filaments of the facial nerve are trapped in scar tissue twitching of the facial musculature can be observed in the affected area.

Blast injury without fracture and without interruption of the continuity of the nerve may also result in facial paralysis (Lathrop, 1946)

Facial paralysis may occur in the course of operations upon the ramus of the mandible, mandibular condyle or the parotid gland resulting from either the sectioning of the nerve, or injury due to stretching the nerve by retraction Paralysis, occurring at the end of twenty four to forty-eight hours after an operation is usually due to pressure caused by postoperative hematoma.

The mandibular branch may be sectioned during operation to remove the submaxillary gland and in incisions made along the lower border of the body of the mandible to expose the bone or to drain a submandibular abscess

The facial nerve is very superficial in the region of the mastoid process in infants at birth prior to the growth of the mastoid process, the stylomastoid foramen and facial nerve are superficial growth of the mastoid process occurs progressively over the first two years of life The nerve may be crushed by forceps in the course of delivery because of its superficial location Facial paralysis, a not uncommon complication of high forceps applications at birth, is less prevalent since the cesarian operation is more frequently employed and the use of forceps is restricted to low applications.

Facial paralysis of unknown origin is usually classified as Bell's palsy

EXAMINATION AND DIAGNOSIS

Clinical Examination

It is important to note whether the paralysis affects all or only a portion of the musculature on one side of the face. Central lesions occurring above the nucleus, result in paralysis with integrity of the upper or temporofacial branch Paralysis affects the entire facial musculature on one side in peripheral lesions Section of branches of the facial nerve anterior to the parotid gland, may result in paralysis of only a portion of the facial musculature.

Facial paralysis which occurs immediately following trauma usually indicates direct injury Paralysis occurring hours or days later may be due to edema, hematoma or secondary infection Paralysis may be complete causing a drooping on one side of the face, or partial resulting in weakness only of the musculature. Although sometimes not obvious especially in early cases and in young patients, the paralysis becomes evident when expressive movements reveal the contrast of the intact musculature on one side of the face with the immobility of the paralyzed side as an attempt to smile becomes grotesque.

The problem is to determine the nature of the lesion whether degenerative or non degenerative, and decide whether the con-

dition can be remedied by surgical intervention the history of the accident and the type of injury inflicted a crash injury with fracture of the skull laceration of soft tissues in the region of the parotid gland or a gunshot wound in the region of the mastoid process Such information usually indicates the location and nature of the lesion

Diagnosis of facial paralysis must be made early in unconscious patients. Movements of the eyelids in such patients are frequently misinterpreted as suggesting that the function of the facial nerve is unaffected (Collier 1954) It should be recalled that closure of the upper lid in patients with facial paralysis occurs by gravity and by relaxation of the levator palpebrae superioris muscle. Lathrop (1952) suggested a test to be used in unconscious patients for the diagnosis of facial paralysis if the trachea is partially obstructed and the accessory muscles of respiration come into play active movements in the alae of the nose indicate an intact nerve absence of movement implies facial paralysis

Diagnosis of Site of Injury

When considering surgical intervention for the repair of the facial nerve the function of all of its branches must be tested to locate the probable site of injury Assistance in diagnosis may be obtained in some cases by testing the sense of taste. The chorda tympani nerve originates from the facial nerve in the region of the geniculate ganglion a lesion situated proximal to the origin of the chorda tympani thus results in loss of taste in the anterior two-thirds of the tongue on the affected side If the sense of taste is not affected, this finding indicates that the lesion is situated in the portion of the facial nerve distal to the origin of the chorda tympani.

The clinical observation of epiphora in the early stages of facial paralysis suggests a lesion at or central to the geniculate ganglion The condition known as crocodile tears, in which there is lacrimation when eating is due to the misdirection or splitting of axons when regeneration occurs secretomotor fibers which are normally carried by the chorda tympani reach the lacrimal gland via the greater superficial petrosal nerve

Hyperacusis occurs on the affected side when the lesion in the Fallopian canal involves the nerve to the stapedius muscle in addition to other signs.

Lesions at the geniculate ganglion are usually associated with considerable pain often herpes of the external ear and canal elevated temperature and signs of facial paralysis (syndrome of Ramsay Hunt)

Lesions in the internal auditory meatus do not produce pain and herpes but present all of the preceding symptoms and signs including tinnitus and deafness.

In lesions of the nerve as it transverses the meninges from the brain to the ear deafness is an associated symptom with involvement of other cranial nerves such as the fifth tenth eleventh and twelfth nerves.

Lesions at the nucleus are associated with an involvement of the sixth nerve because of the proximity of the nuclei of the nerves, and a contralateral hemiplegia.

Supranuclear lesions are associated with a homolateral hemiplegia with only the lower two-thirds of the face paralyzed. The sensations of taste and salivation are not involved and hyperacusis is not present. The nerve branch to the frontalis muscle has bilateral cortical innervation and is therefore spared in unilateral cortical lesions involving the motor area of the face.

Electrodiagnosis*

Examination of the patient with facial paralysis is completed by electrodiagnostic studies which define the character of the nerve lesion and aid in establishing the prognosis These tests however although adjuncts to accurate diagnosis, do not relieve

* Contributed by Joseph Goodgold M.D., Director Electrodiagnostic Section Institute of Rehabilitation and Physical Medicine New York University Bellevue Medical Center

the surgeon of clinical diagnostic responsibility A simple routine of electrodiagnostic *investigation of facial nerve paralysis may* be established as follows, noting that a battery of tests examining various aspects of neuromuscular function is utilized (1) percutaneous stimulation of the facial nerve (2) *percutaneous stimulation* with faradic and galvanic current, of the various muscles innervated through the seventh nerve observing qualitative and quantitative responses and (3) electromyography

1 Percutaneous Nerve Stimulation

Percutaneous stimulation of peripheral nerves is a simple procedure but is frequently neglected. The subcutaneous position of the facial nerve in the pre-auricular area permits such a study Extremely short duration stimulation may be used to produce a response because nerves characteristically have a low threshold of excitation This type of current is not painful and is well tolerated by the patient even with relatively high voltage. Careful observation of the response to stimulation of the nerve is essential including visualization of the contraction in each individual muscle innervated through the seventh nerve Partial denervation may be readily identified in this manner With complete lesions there is no perceptible reaction to stimulation.

2 Percutaneous Stimulation of Muscles

The response of a muscle to electrical stimulation can be studied by applying a current to the skin which overlies the point of entrance of the nerve into the muscle belly the motor point.

FARADIC TESTING Faradic stimulation employs the electrical outflow from the secondary of an inductance coil the current is alternating with a frequence of approximately 100 to 150 cycles per second *It has a very* short low wave on make which is not significant but has a sharp spike with a duration of 1/1000 second (one millisecond of sigma) on break of current, which is the effective stimulus it is the duration of one sigma that lends usefulness to faradic current in electrodiagnosis. *This is* true because normal muscle has an average maximum time requirement for stimulation (chronaxie) of one millisecond and therefore will contract if faradic current of adequate intensity is applied. *The chronaxie is characteristically* increased if denervation is present the effective duration of the faradic current will then be too short and no response will occur *It is evident therefore, that faradic* stimulation is only of value in the gross detection of denervation The current, however causes pain even with moderate intensity and patients find it intolerable.

GALVANIC TESTING Galvanic current is unidirectional of known polarity stimulation being applied in a physiological manner through the negative electrode. Direct muscle stimulation requires concise observation of the quality of the contraction. Normal muscle contraction is rapid and sharp Denervated muscle responds with a relatively slow rise, a slower fall and a tendency to spread to contiguous fibers the result being a sluggish spreading vermicular contraction The current intensity required to elicit a minimum contraction (rheobase) varies with the time interval following injury There is no change in intensity requirement for the first ten days. Then a rise of short duration is followed by a well marked and prolonged fall of the required current. A sharp rise in the intensity requirement is frequently a prelude to reinnervation The early observed fall in rheobase is in accord with the general principle of hypersensitivity of denervated structures as postulated by Cannon Classical Erb testing does not take cognizance of this fact and specifies that increased current requirement means degeneration Slowly contracting fibers are a characteristic finding in denervation and are most readily seen in complete lesions. The partial lesion poses the greatest problem and elucidation may require studying the response with stimulation away from the

motor point to bring out slow fiber contractions. The use of progressive current to establish the inability of denervated fibers to accommodate to a slowly rising current is also helpful in identifying partial lesions.

Determination of rheobase is subject to errors of procedure and conditions of examination the more accurate determination of chronaxie may be used In this study intensity of current is not a variable but the duration of current flow required to give the same minimum visible contraction as visualized in the rheobase is recorded Chronaxie determinations are accurate reproducible studies which are highly significant in the detection and prognostication of the course of denervation states The normal chronaxie values vary from 0 04 to 0 08 sigma with an approximate normal value for skeletal muscle of less than one millisecond A characteristic elevation of chronaxie in denervation may go to fifty or more sigma Reinnervation is characterized by a progressive fall toward normal

Chronaxie determinations represent the application of a formula which relates muscle response stimulus duration and stimulus intensity this may be presented as follows

K (local excitatory state)

$$= (k) \text{ (intensity } \times \text{ duration)}$$

Strength-duration (S D) curves are also based on this formula but instead of one reading, a series of points of varied intensity and duration is established where K is attained A strength-duration curve, in which these points are plotted and graphed, represents a series of chronaxies which offers statistical advantages over unitary determinations A study of the shape of the curve affords additional prognosticative information The normal S-D curve is essentially flat showing a rise only at the zero end of the time abscissa Denervation is characterized by a sharply progressing shift of the curve to the right a fall in the rheobase and a rise in chronaxie Reinnervation is characterized by a shift of the curve to the left a fall in chronaxie a rise in rheobase and the appearance of plateaus Serial strength duration curve studies therefore offer excellent prognostic determinations

Other tests such as the galvanic tetanus ratio response to repetitive stimulation with varying frequence and response to progressive currents are useful but somewhat more difficult to achieve as well as to interpret

3 *Electromyography*

Electromyography deals with the detection and recording of the minute electrical potentials generated by normal and abnormal muscles Since the details of the technical aspects of recording electromyograms and electromyographic equipment have been extensively described it is pertinent to note only that the electrical output of the muscle is detected with needle or surface electrodes and fed into the amplifier system. From here the electromotive force is directed to two outputs (a) the cathode ray oscilloscope and (b) the loudspeaker where the electrical energy is converted to audible sound. The latter is entirely feasible since the rate of repetition of motor unit discharge is within the lower confines of the audible frequency range The muscle potentials may thus be heard and visualized simultaneously The usual apparatus is completed by a permanent recording device such as a tape recorder or kymographic motion picture camera The surface electrodes are useful in the study of gross electrical patterns of muscle activity but needle electrodes must be employed where single units are to be considered. These may be either of a monopolar variety generally consisting of an ordinary sewing needle coated except at the tip with an insulating material An indifferent electrode is applied at a distance In other instances a concentric needle electrode is employed this consists of an enamelled magnetic wire fixed within the shaft of a 25-gauge hypodermic needle Details of po-

tential pattern vary with reference to the type of electrode employed. Electromyograms, in most instances, should be recorded in a well-shielded room since the required amplification factor is such that low amplitude extraneous noise is readily picked up as interference.

A normal voluntary muscle at complete rest is electrically silent. An electrical potential is generated with voluntary or reflex contraction and appears on the cathode ray screen as a biphasic or triphasic wave. This potential is known as a motor unit and has been defined by Denny Brown and Pennybacker as the functional unit of the nervous system consisting of one anterior horn cell its axon and its dependent group of muscle fibers In addition to the motor unit a normal muscle may show approximately 5 per cent of waves with multiple spikes these are referred to as complex or polyphasic waves. The motor unit is associated with a characteristic sharp popping sound emitted by the audio output.

Injury to peripheral nerves such as the facial is associated with characteristic abnormal voltages. When the nerve supply to a muscle has been disrupted the denervated muscle will show fibrillation after a variable period of time depending on the animal species. Except for the tongue, such twitchings are not visible grossly and can only be detected electronically The appearance of the abnormal muscle contractions has been accounted for on the basis of a hypersensitivity of the denervated fibers to the minute quantity of acetylcholine which is normally present in the circulation There appears to be a positive correlation between the time of appearance of denervation fibrillation and the basal metabolic rate of the species studied. Fibrillation following nerve resection for example appears after a four day lapse in the rabbit, eight to thirteen days in the cat, and between eighteen to twenty-one days in man *Denervation fibrillations are present* in the resting state. The waves are relatively small usually diphasic in configuration and are associated with a sound similar to the clicking of radio static or the rustling of crumpled wax paper Fibrillary potentials are present until reinnervation occurs or until the muscle undergoes complete loss of contractility and fibrosis.

The motor unit voltages consistently associated with reinnervation are polyphasic in character These may appear from several days to several months previous to the return of function Because of their association with early recovery the term nascent motor units was introduced. Polyphasic waves may show up to twenty spikes and are associated with a sound similar to the chug-chug of the old model "T" Ford.

In recapitulation it may be stated that reinnervation is represented electromyographically by a progressive decrease in fibrillation the appearance and increase in number of complex waves, which is superseded by normal motor unit discharges. Although electromyography has its greatest application in the study of peripheral nerve lesions, it may also be of aid in the observation of patients with peripheral neuropathy such as diptheritic neuritis, in definitive myopathies such as fascio-scapular dystrophy and myotonia congenita, and in such primary neurogenic disorders as amyotrophic lateral sclerosis. The state of reinnervation of paralyzed muscles may be ascertained by a combination of electromyograph and other electrodiagnostic tests. Interpretation of the readings, however is sometimes difficult it is therefore desirable that one well versed with the techniques be present at all determinations.

THE DEVELOPMENT OF FACIAL NERVE SURGERY

Bell (1821) described the course of the seventh cranial nerve and presented a number of cases of facial paralysis at a scientific meeting to support his thesis that the facial nerve was anatomically and functionally *differentiated from the trigeminal nerve*

The earliest nerve suture experiments were those of Flourens (1827) who also dem-

onstrated the splitting of the neurons in one of his experiments the nerve fibers previously conveying impulses to the extensor muscles subsequently conducted impulses to a flexor group of muscles.

Since the year 1895 surgeons have been uniting the peripheral end of the divided facial nerve to the central end of an adjacent motor nerve The results of these operations are satisfactory as compared with the original paralysis but are not functionally entirely satisfactory In focusing the attention on the restoration of function of the muscles of facial expression the surgeon was apt to ignore associated disabilities resulting from these operations When the facial nerve was anastomosed either to the hypoglossal descendens hypoglossi, or glossopharyngeal nerves, associated movements occurred which varied from slight closure of the eyelids to contractions involving other muscles of the face and pinna. The mediocre results attained by such operations are exemplified in the following story told by Ballance (1934)

In 1920 he had operated for facial paralysis upon a young lady by performing an anastomosis between the facial and hypoglossal nerves. Three years later he was invited to a dinner at which she was present. During the dinner Ballance who was sitting opposite his patient, had an opportunity to observe her face. The lady sitting on his left said to him Oh Sir Charles is this the result of your great surgical triumph? for each time his patient spoke there was an absence of contraction of the muscles of the face on the affected side but when she swallowed a mouthful of food a wave of contraction occurred which produced a most grotesque effect.

Clinical repair of the peripheral nerves by anastomosis of the divided ends has been practiced since it was first undertaken by German surgeons at the beginning of World War I Ballance (1934) pointed out that in the so-called *anastomosis operation* there is no true anastomosis, for the distal segment of the nerve degenerates and after fourteen days may be described as a bundle of tubes containing the broken down fatty elements of the nerve sheath. The axons of the central segment of the nerve slide along the tunnels, pushing aside the lipoid masses until they reach the motor end-organs of the muscle or muscles which had been in connection with the fibers of the distal segment. The new fibers thus replace the old and conduct the nerve impulses which cause contraction of the muscle fibers

The injured nerve was decompressed in the Fallopian canal in early efforts to repair the facial nerve. Ballance mentions that the first decompression of the facial nerve in the Fallopian canal was accomplished by Alt in 1908 Bunnell (1927) performed and end-to-end suture of the facial nerve after rerouting the nerve to obliterate a 12 mm. defect.

The contribution of Ballance and Duel (1932) opened the way to the repair of the facial nerve by nerve grafting in injuries and defects of the nerve within the mastoid area Ballance and Duel felt that the use of a previously degenerated graft favored the growth of axons from the central segment into the graft. Many reports followed the original articles by Duel and Ballance, among them were those of Tickle (1945) Collier (1949) and Sullivan (1952) The practice of employing previously degenerated grafts was discarded in favor of fresh nerve grafts

To repair a gap in the main trunk of the facial nerve, in addition to nerve grafting, direct anastomosis of the main trunk of the seventh nerve has been done after rerouting the nerve to shorten it. This procdeure requires a radical mastoidectomy the nerve being short-circuited to compensate for the loss of a portion of the nerve trunk. A gap in the facial nerve as great as 23 mm may be repaired by direct anastomosis after rerouting (Bunnell 1937) Direct anastomosis has been considered a superior procedure to nerve grafting because one neural junction is eliminated thus one possible obstacle to the downgrowth of axons from the central

tential pattern vary with reference to the *type of electrode employed* Electromyograms, in most instances, should be recorded in a well-shielded room since the required amplification factor is such that low amplitude extraneous noise is readily picked up as interference.

A normal voluntary muscle at complete rest is electrically silent. An electrical potential is generated with voluntary or reflex contraction and appears on the cathode ray screen as a biphasic or triphasic wave This potential is known as a motor unit and has been defined by Denny Brown and Pennybacker as the functional unit of the nervous system consisting of one anterior horn cell its axon and its dependent group of muscle fibers In addition to the motor unit, a normal muscle may show approximately 5 per cent of waves with multiple spikes these are referred to as complex or polyphasic waves The motor unit is associated with a characteristic sharp popping sound emitted by the audio output.

Injury to peripheral nerves such as the facial is associated with characteristic abnormal voltages When the nerve supply to a muscle has been disrupted the denervated muscle will show fibrillation after a variable period of time depending on the animal species. Except for the tongue, such twitchings are not visible grossly and can only be detected electronically The appearance of the abnormal muscle contractions has been accounted for on the basis of a hypersensitivity of the denervated fibers to the minute quantity of acetylcholine which is normally present in the circulation There appears to be a positive correlation between the time of appearance of denervation fibrillation and the basal metabolic rate of the species studied. Fibrillation following nerve resection for example appears after a four day lapse in the rabbit eight to thirteen days in the cat and between eighteen to twenty-one days in man Denervation fibrillations are present in the resting state The waves are relatively small usually diphasic in configuration and are associated with a sound similar to the clicking of radio static or the rustling of crumpled wax paper Fibrillary potentials are present until reinnervation occurs or until the muscle undergoes complete loss of contractility and fibrosis.

The motor unit voltages consistently associated with reinnervation are polyphasic in character These may appear from several days to several months previous to the return of function Because of their association with early recovery the term nascient motor units was introduced Polyphasic waves may show up to twenty spikes and are associated with a sound similar to the chug chug of the old model 'T' Ford.

In recapitulation, it may be stated that reinnervation is represented electromyographically by a progressive decrease in fibrillation the appearance and increase in number of complex waves, which is superseded by normal motor unit discharges. Although electromyography has its greatest application in the study of peripheral nerve lesions, it may also be of aid in the observation of patients with peripheral neuropathy such as diptheritic neuritis in definitive myopathies such as fascio-scapular dystrophy and myotonia congenita and in such primary neurogenic disorders as amyotrophic lateral sclerosis. The state of reinnervation of paralyzed muscles may be ascertained by a combination of electromyograph and other electrodiagnostic tests. Interpretation of the readings however is sometimes difficult it is therefore desirable that one well versed with the techniques be present at all determinations.

THE DEVELOPMENT OF FACIAL NERVE SURGERY

Bell (1821) described the course of the seventh cranial nerve and presented a number of cases of facial paralysis at a scientific meeting to support his thesis that the facial nerve was anatomically and functionally differentiated from the trigeminal nerve

The earliest nerve suture experiments were those of Flourens (1827) who also dem

onstrated the "splitting of the neurons" in one of his experiments, the nerve fibers previously conveying impulses to the extensor muscles subsequently conducted impulses to a flexor group of muscles.

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stump of the facial nerve into the peripheral segment is removed (Lathrop 1946) Tickle (1918) however reported that his results with nerve grafting were superior to those with direct anastomosis.

Most repairs of the facial nerve have been done in the intratemporal portion of the facial nerve which had either become diseased as a result of suppurative mastoiditis, or injured or severed in the course of mastoidectomy With the advent of antibiotics and the control of otitic and mastoid infection followed by a decrease in the number of mastoid operations, a proportionate increase in the number of cases has occurred which require repair of the extratemporal portion of the facial nerve Duel (1934), in a report of a series of facial nerve grafts included one case in which removal of the parotid gland resulted in defects of facial nerve branches which required four grafts aggregating 150 mm in length the end result of this case was not described. Bunnell (1937) described suturing the main trunk of the facial nerve and its small branches after their severance due to facial lacerations He also reported the first successful extratemporal repair of the facial nerve done by nerve grafting a case in which a malignant tumor had necessitated removal of the parotid gland and facial nerve branches Repair was achieved by means of two grafts from the sural nerve each 6 cm in length one of which was split at one end to permit anastomosis to three distal branches. Cardwell (1938) reported a case in which a parotid tumor was removed and the facial nerve sacrificed three nerve grafts, 6 cm. in length were sutured to the proximal stump of the nerve and their free ends were implanted in the facial muscles. A good functional result was reported in the follow-up of this case (Cardwell 1956) muscle tone was re-established and mass movement of the musculature occurred

Later reports by Maxwell (1951) and Lathrop (1953) described the preservation and repair of the facial nerve in operations for tumor removal in the parotid region and following traumatic injuries of the nerve or its branches.

The results of a successful operation to repair a damaged main trunk of the facial nerve are not perfect due to the "splitting of the neurons varying degrees of mass motion occur fine emotional responses are not restored and associated movements may occur The re-establishment of muscle tonus restores symmetry of the face, however and eliminates the grotesque appearance on the unaffected side of the patient at rest and during expressive movements.

Such inconveniences do not occur in the repair of peripheral branches of the facial nerve by grafts the nerve fibers eventually find their way to the muscles.

INTRATEMPORAL REPAIR OF THE FACIAL NERVE

Two surgical procedures are commonly used in the repair of facial nerve injuries the decompression operation and the nerve graft Preference for one procedure over the other depends on the type, location and degree of the injury If the facial nerve is exposed in the course of an operation in the mastoid or middle ear cavity the entire portion of the nerve located distally to the exposed area should be decompressed to the stylomastoid foramen Localized edema and compression of the nerve within the Fallopian canal are thus avoided (Bellucci 1957).

Facial paralysis, immediately following a mastoidectomy usually indicates severe nerve injury When the nerve is completely severed faradic stimulation is usually lost within seventy two hours and sagging of the face with lack of tonus results. The nerve should be explored surgically and the damage repaired. Similar principles should govern the treatment of facial paralysis following fractures of the petrous bone In such fractures the location of the injury as determined by symptoms and signs, determines

Contributed by Richard J Bellucci M D Surgeon Director in charge of Hearing and Speech Clinic Manhattan Eye Ear and Throat Hospital

whether the lesion is surgically accessible Surgical procedures are not feasible if the injury is more proximal than the geniculate ganglion

Paralysis which develops several days after a surgical procedure or an injury usually indicates that the nerve has sustained slight damage and that paralysis is the result of edema or hematoma The faradic response is usually maintained the prognosis for recovery is favorable if the response is sustained. A decompression operation is indicated if the faradic response is lost and there is no improvement in tonus of the facial muscles and no perceptible movement after three months. Electromyography offers an accurate basis for prognosis in most cases of this type Improvement in the strength-duration curve, chronaxie tetanus ratio and the rheobase ration suggest a favorable prognosis, and surgery is deferred. These newer electrical tests are of great assistance in those cases in which the faradic response is lost but some degree of tonus is maintained. *Electromyography is a determining factor in deciding whether to await the return of function or to intervene surgically*

The galvanic current acts directly on the muscle fibers Loss of galvanic response or signs of poor muscular response by electromyography indicate that the muscles have become atrophic and fibrosed. It is useless to perform a nerve repair when the muscle is incapable of being reinactivated In such cases, fascia lata slings alone are indicated or combined with transposition of muscle flaps from muscles innervated by the fifth nerve.

The Duel Ballance Operation

Injury to the nerve occurs most frequently in the course of a mastoidectomy in such conditions a partially exenterated mastoid bone with few normal landmarks are encountered during surgical repair following traumatic injury and Bell's palsy however the mastoid bone bears natural landmarks The safest approach to the facial nerve is at the stylomastoid foramen exposure is then extended upward into the middle ear

The postauricular or endaural approach may be employed for decompression or nerve graft in facial paralysis following mastoidectomy The periosteum is elevated and the old postoperative cavity is cleared of granulations and scar tissue The attachment of the sternocleidomastoid muscle is separated from the tip of the mastoid process, and the tip and inferior wall of the tympanic bone are removed with a rongeur The posterior belly of the digastric muscle is encountered and the fan like sheath of the facial nerve is located as it emerges from the stylomastoid foramen The digastric groove is helpful in locating the foramen, for it extends directly toward the opening The styloid process can be located deep and slightly anterior to the foramen the nerve curving superficially to the mastoid process as it turns outward and forward to enter the parotid gland.

The use of a magnifying loupe offers a degree of assurance against injury to the nerve. The posterior canal wall is partially removed with an electrically driven burr until the stylomastoid artery superficial to the nerve, is uncovered. The remainder of the bone is removed with curettes and dental excavators. The roof and sides of the Fallopian canal are removed as far superiorly as the geniculate ganglion The nerve is carefully inspected for atrophy or areas of injury A large neuroma usually covers the site of the injury this is formed by nerve fibers which grow from the proximal end and with no path to follow roll upon themselves to form a firm mass of tissue The neuroma is dissected away and an estimate is made of the remaining uninjured portion of the nerve.

When the nerve appears intact and only superficial injury is suspected, a simple decompression of the nerve trunk suffices. The sheath of the nerve is slit from the stylomastoid foramen to the geniculate ganglion. This is done under magnification with a thin bladed knife, carefully engaging only the

sheath No constricting bands in the sheath should remain uncut.

When a greater portion of the diameter or a segment of the nerve is destroyed or is atrophic, a nerve graft is necessary Intact fibers of the nerve must not be removed or injured further The proximal and distal ends of the injured portion are incised cleanly The sheath is slit from the foramen to the geniculate ganglion and a segment of nerve from the anterior femoro-cutaneous nerve of the thigh is placed beside the intact fibers. This graft should fit snugly against the cut ends of the nerve insuring that no blood clot has accumulated between the graft and the ends of the nerve. Suturing the nerve is not necessary as the fibrin from the blood in the wound retains the graft in position Gold leaf is placed over the entire length of the nerve and graft. The bright gold color permits localization of the nerve during postoperative dressings and avoids injury

EXTRATEMPORAL REPAIR OF THE FACIAL NERVE

Two techniques may be employed to expose the site of the lesion of the trunk of the facial nerve or one of its branches (1) The trunk may be exposed and the nerve and its branches dissected posteroanteriorly or (2) one of the terminal branches of the nerve may be exposed and traced back to the area of division and thus to the main trunk.

Extratemporal Exposure of the Trunk of the Facial Nerve

An incision in the preauricular area extends to the lobe of the ear the incision is then curved backward over the mastoid process A counter incision which extends downward along the anterior border of the sternomastoid muscle may also be made for better exposure The cheek tissues are reflected forward after incision and a cleavage plane is found between the perichondrium of the auricular cartilage and the capsule of the parotid gland (Maxwell 1951) The posterior lobe of the parotid gland is lifted away and the styloid process is palpated and located The trunk of the facial nerve is found by dissecting the tissue immediately in front and deep to the sternomastoid muscle In exposing the facial nerve in this area it should be recalled that the nerve is usually invested in fascia and is accompanied by the stylomastoid artery which bleeds abundantly if severed. The origin of the posterior belly of the digastric muscle on the mastoid process is an additional landmark in locating the nerve for the trunk is found immediately above the origin of the muscle When exposed the nerve trunk is seen beneath the external auditory canal assuming a direction almost at right angles to the stylomastoid foramen

The removal of a portion of the mastoid facilitates the exposure of the trunk of the facial nerve in short necked patients with a long overhanging mastoid process.

Exposure of a Peripheral Branch of the Facial Nerve

To expose the branches of the nerve in the parotid gland one of the peripheral branches anterior to the parotid is located, and the nerve filament is traced back to the area of the lesion The scar is excised, if scar tissue is present over the parotid area and the wound is used as the means of approach to the facial nerve When there is no scar a periauricular incision is made with a counterincision downward along the anterior border of the sternomastoid muscle the tissues are then reflected forward to expose the anterior border of the parotid gland and Stensen s duct and the facial branch may be identified by carefully stretching the tissues and by dissection in the area noting the resistant string like cords of the nerve The buccal branch is usually found in close proximity to Stensen s duct. The mandibular branch is identified through an incision along the lower border of the body of the mandible at the anterior border of the masseter muscle and is located in proximity to

the external maxillary artery and anterior facial vein The mandibular branch may also be identified more posteriorly by exposing *the posterior facial vein* the nerve is usually very close to the vein.

In all of these procedures identification of the nerve trunk or branches is facilitated by the use of the faradic stimulator

Repair of Facial Lacerations with Section of Facial Nerve Branches

Because the superficial facial muscles are innervated in their posterior portions sectioning through the cheek anterior to the *region of Stensen s duct,* does not result in permanent loss of muscle function Section of one of the branches may also not necessarily be followed by permanent loss of function as axons may grow from an anastomotic branch to rehabitate the sectioned nerve

A clean-cut laceration through the parotid gland such as with a razor blade, may not require surgical exploration for approximation of the skin edges of the wound results in apposition of the sectioned surfaces of the nerve spontaneous nerve repair may occur satisfactorily A penetrating wound in the tissues immediately anterior to the parotid gland which severs Stensen s duct and the buccal branch of the nerve results in a characteristic fluctuant soft tissue swelling and a drooping of the upper lip on the affected side The orbicularis oris and nasalis muscles are paralyzed. Drainage of salivary fluid through an external fistula and infection may occur in the wound resulting in mechanical separation of the ends of the sectioned nerve branches and also scar tissue which prevents healing of the nerve ends. Stensen s duct should be repaired by end to end anastomosis whenever possible (see Fig 92, Chapter 4) The severed ends of the buccal branch should be sutured when possible. Spontaneous regeneration, however appears to occur quite readily in these terminal branches of the facial nerve In three successive cases (Converse and Goodgold, 1959) in the absence of surgical treatment clinical and electromyographic studies have revealed return of function of the paralyzed muscles after periods of time varying from five to twelve months (Fig 1059)

Gunshot wounds with loss of tissue and particularly when followed by severe infection result not only in separation of the nerve ends due to tissue loss but also in the formation of dense scar tissue which acts as a barrier to nerve regeneration

Faradic stimulation is helpful in identifying the facial nerve or its branches. The Maxwell faradic nerve tester used in the operating room can deliver from five to fifty volts. When the stimulating electrode is placed directly on the facial nerve trunk, a minimum amount of voltage is employed to produce a twitch of the facial muscles It is necessary that the field be dry to avoid spread of the current and to accurately locate the nerve

When seeking to locate the peripheral portion of a sectioned facial branch it should be recalled that there may be an absence of response to electric stimulation even during the first 48 hours after section and even in the hours immediately after section of the nerve a current of higher intensity is required to obtain a response. No response is observed after the third day and the nerve can be identified with careful dissection.

Immediate exploration and identification of the severed nerve ends and their direct approximation and suture should be done in the early stages before infection and dense scar tissue renders the task more difficult if not impossible. If the nerve is damaged the injured portion is resected with the edge of a razor blade, and the freshened nerve ends are approximated with the finest available silk sutures the procedure is best done under magnification If the gap is too wide to permit approximation, a nerve graft is employed to re-establish the continuity of the nerve.

Various techniques have been recommended for nerve suture It is often possible to pass one or two sutures through the neural

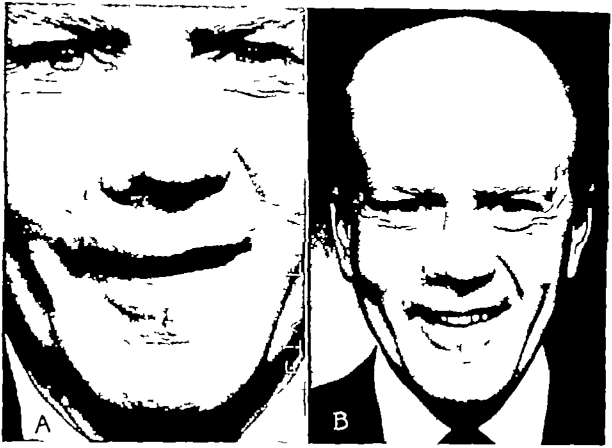


Fig 1059 Spontaneous recovery of the buccal branch of the facial nerve

A. Buccal branch severed on right side by deep penetrating laceration in the nasolabial area. Note the drooping of the right side of the upper lip.

B. Complete recovery of function eleven months after injury

sheath under magnification using very fine needles and suture material

Donor Sites of Nerve Grafts for Repair of the Facial Nerve

Ballance and Duel (1932) employed the anterior femorocutaneous nerve To obtain a graft from this nerve, a transverse incision is made in the skin of the thigh over the sartorius muscle one handbreadth below the inguinal ligament The incision is extended through the superficial fascia and fat to the fascia lata which covers the sartorius muscle The external saphenous vein is thus exposed and two branches of the anterior femorocutaneous nerve can usually be seen piercing the fascia lata at a point 2 to 1 cm lateral to the vein over the sartorius muscle and extending distally (Fig 1060) The nerve is dissected from the surrounding tissue and a segment of slightly longer length than required is removed. The nerve should be handled with skin hooks and should be kept moist with normal saline solution at all times

Maxwell (1951) advocated the use of the greater auricular and lesser occipital nerves (Fig 1061) These nerves are in close proximity to the operative site The greater auricular nerve can be located on the lateral surface of the sternomastoid muscle by exposing the external jugular vein the nerve usually lies immediately posterior to the vein The lesser occipital nerve is found on the posterior border of the sternomastoid muscle at the junction of the lower two-thirds of the muscle

Bell's Palsy

Although the etiology of facial paralysis in Bell's palsy is unknown it is generally believed that edema of the nerve occurs as the

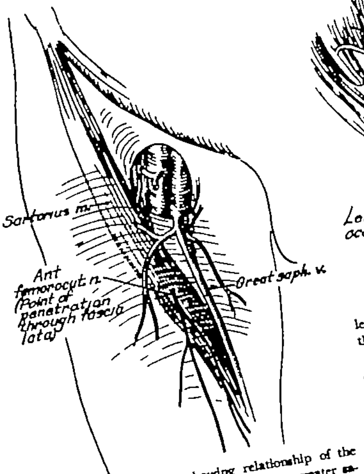


FIG 1060 Drawing showing relationship of the anterior femorocutaneous nerve and the greater saphenous vein and the anterior-femorocutaneous nerve piercing the fascia lata over the sartorius muscle

result of ischemia Over 80 per cent of all cases recover spontaneously the circulation being temporarily obstructed causing edema of the nerve the remaining 20 per cent are severely damaged Attempts have been made to differentiate these cases from the mild cases which recover spontaneously It is difficult to establish this differentiation early enough to relieve the ischemia as none of the electrical tests are significant. Faradic stimulation usually brings a response for as long as seventy-two hours in the severe as well as in the mild cases Electromyography is of no assistance in early recognition of severe cases The reaction of degeneration in muscles is not present until a period of a week has elapsed If ischemia is to be relieved without damage to the nerve the

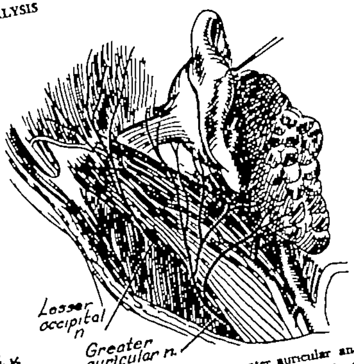


FIG 1061 Drawing of the greater auricular and lesser occipital nerves showing their relationship to the posterior border of the sternomastoid muscle.

decompression operation should be done within the first few hours of the onset of paralysis

The early symptoms are the most reliable in differentiating the mild from severe cases. Sudden onset of paralysis accompanied by severe pain in the ear loss of the sense of taste complete flaccidity of facial muscles and a diminution of tearing are indicative of severe injury to the nerve and are indications for immediate surgical decompression The usual practice is to postpone surgery until diagnostic assistance is provided by electrical tests. Within two or three months if no improvement is noted the facial nerve should be decompressed by uncovering the Fallopian canal as far as the horizontal semicircular canal without disturbing the ossicles and the middle ear

Postoperative Treatment in Facial Paralysis

1 *Galvanism* There is some evidence that the use of daily stimulation of the facial musculature by galvanic current retards atrophy and helps maintain contractility (Gutmann and Gutmann 1942 Jackson and

Seddon 1945) although there is some feeling that galvanic stimulation is responsible for contractures.

2 *Splinting* Splinting of the paralyzed face can be done by means of adhesive tape or elastoplast, supporting the skin of the paralyzed side by means of a hook-type apparatus that supports the angle of the mouth, or by means of an intraoral appliance applied to the upper teeth and provided with an extension to support the angle of the mouth Insertion of fascial strips have been thought likely to damage the muscles inserted into the skin (Collier 1950)

3 *Exercises* Exercises should be prohibited until there is clinical evidence of active movements. Overaction of the sound side in efforts to move the denervated muscles on the paralyzed side increases stretching while movements of the muscles supplied by the fifth cranial nerve lead to grimaces and further stretching Exercises and voluntary movements should be undertaken only with the sound side firmly controlled by the hand, in order that the recovering muscles are not subjected to the strain offered by strong antagonists

Results Following Facial Nerve Repair and Grafting

Recovery of function in all cases is gradual regardless of the type of surgical repair for the regrowth of nerve fibers extends from the site of injury to the nerve endings in the facial muscles which have undergone Wallerian degeneration The sequence followed in the return of function is usually constant. An increased tonus in the muscles of the face on the involved side is noted first. The face appears more symmetrical and evidence of paralysis is seen only when smiling or in attempting other facial movements Food no longer collects in the cheek and loss of liquids from the corner of the mouth ceases The lower lid shows less tendency to sag The first sign of motion is usually noted at the angle of the mouth or the ala of the nose The ability to contract the facial muscles continues to increase and the lower lid begins to show motion The frontalis muscle is the last to recover and often fails to regain function

All cases which have recovered from a facial paralysis involving the trunk of the seventh nerve show varying signs of splitting of the neurons. The eye on the same side blinks when the patient smiles. A variety of other similar associated movements can occur these can be minimized by re-educating the paralyzed muscles In this way the patient can assist in adjusting the facial contractions and minimize the residual deformity by practicing muscular movements before a mirror

While awaiting return of voluntary function the sagging facial muscles should be supported by a sling at the angle of the mouth massage should be given manually and by means of galvanic stimulation to prevent muscle atrophy Medication does not hasten the return of function or improve the residual deformity which remains.

The maximum length of the graft that may be expected to be followed by success in nerve grafting of the trunk of the nerve is still unknown. Grafts 10 to 15 mm in length are commonly used successfully and good results have also been reported with nerve grafts of greater length As previously stated, nerve grafting of the trunk can restore muscle tone to all the facial musculature except the frontalis The explanation for the lack of regeneration of the frontalis branch is not known the long and tortuous course of this nerve has been suggested as a possible explanation Splitting of the neurons and associated movements often impair an otherwise satisfactory result after nerve grafting of the trunk of the nerve this is not encountered in the repair of the branches of the nerve the nerve fibers finding their way to the muscles The following case history of a patient operated upon by Dr James H Maxwell is illustrative of the type of result obtained following nerve grafting of the branches of the facial nerve

FIG 1062. Repair of branches of the facial nerve by nerve grafts

A. Complete left-sided facial paralysis.

B. Symmetry of the face re-established by nerve grafts. Patient smiling

C. Postoperative view showing face in repose.

D Postoperative view demonstrating the expressive movements of the face and adequate closure of the left eyelids.

E. Postoperative view showing patient's ability to whistle.

F Restoration of function of the left frontalis muscle is incomplete.

(FIGS. 1062 and 1063 courtesy of Dr James H Maxwell)

The patient, a white male aged 17 years, had suffered a severe laceration of the left side of his face in an automobile accident. He was reported to have been unconscious for three or four hours but had no residual neurological symptoms Prompt suture of the wound had been accomplished under general anesthesia

Examination revealed multiple recent scars on the left side of the face Most prominent was a long irregular scar from the tragus of the left ear to the corner of the mouth on the same side. Also as noted in the preoperative photograph (Fig 1062*A*) there were scars of the left side of the lower lip and right side of the face Motion of the lower lip and action of the platysma indicated that the mandibular ramus and the cervical branch of the facial nerve were intact. The facial muscles above the lower lip were functionless. Neurological and general physical examination demonstrated no pathologic changes other than the facial paralysis

An operation was performed three weeks after the accident The diagonal wound across the left cheek from the tragus to the corner of the mouth was reopened and the hypertrophic scar excised. The parotid gland contained a mass of scar tissue which made identification and isolation of the branches of the facial nerve difficult. The mandibular ramus of the nerve was found to be intact but all of the branches superior to it had been severed. After debridement, four free grafts were used to repair the four severed branches of the nerve which had been identified (Fig 1063) The greater au

Fig 1063 Showing direction of the branches of the facial nerve and nerve grafts repairing defects in the branches. The mandibular marginal branch alone was intact The junction points of nerve grafts and seventh nerve branches are indicated by white arrows.

ricular nerve on each side of the neck served to supply these grafts

The patient's convalescence was uneventful and he was discharged from the hospital seven days after the operation.

Four months after the nerve repair examination revealed good tone of the facial muscles which seemed to presage return of function. The patient had not been aware of any movement of the facial muscles but very slight movement in the upper lip was detected

The patient was not seen again until twelve and one-half months after operation return of muscular function had occurred during the preceding summer The general condition was excellent and the result of the nerve repair was most gratifying A slight degree of frontalis muscle function had also occurred (Fig 1062*D*)

The most interesting feature of this case is the minimum of mass motion far less in fact than is seen after most nerve repairs involving the main trunk. In all probability this is due to the lessened opportunity for axonal confusion during regeneration through the grafts in the individual branches of the nerve

Associated Movements

Residual abnormalities of varying degree are observed in almost every case in which injury of the facial nerve has resulted in degenerative changes. Young (1942) pointed out that (1) not all of the axons at the proximal end of the damaged nerve regenerate (2) each regenerating axon subdivides into several fibers and (3) the orientation of the fibers differs from the original pattern This particular mode of regeneration accounts for the mass action of the involved facial muscles which may occur Persistent tearing is also accounted for on this basis Simultaneous contraction of the orbicularis oculi muscle with the musculature of the lower face has also occurred.

It has been noted that the frequence of sequelae following the repair of the facial nerve is increased in lesions affecting the main trunk of the nerve. Repair and grafting of the peripheral branches of the facial nerve are not usually followed by associated movements.

The "Crocodile Tear" Syndrome

When injury to the facial nerve occurs proximally to the geniculate ganglion it is possible for lacrimal fibers which normally reach the submaxillary gland by means of the chorda tympani nerve, to be misdirected to the lacrimal gland through the greater superficial petrosal nerve (Fig. 1064) As a result of this condition the patient suffers from lacrimation when eating (Boyer and Gardiner 1949) This syndrome is known as the "crocodile tear syndrome a reference to the remorse allegedly expressed by the crocodile when devouring the missionary who had inadvertently fallen into the river! Treatment consists of dividing the greater superficial petrosal nerve

Facial Muscle Spasm (Tic)

Spontaneous contraction of the muscles of the face occurs when recovery of the function of the facial nerve is long delayed and more or less imperfect. It is observed frequently following lacerations involving the branches of the facial nerve Some muscles remain paralyzed, others offer a poor response to faradic stimulation and others, notably those around the angle of the mouth show the spontaneous twitch described as the "winking reflex. The twitch may be elicited by stroking the eyelids or the face stroking the eyelids often increases the spasm. Excitement or fear increases the muscular contraction The risorius muscle is frequently involved in spasm this may be noted even when no muscular response can be elicited by faradic current applied to the skin. The twitch may be rhythmical and continuous, or there may be intervals of quiescence between the spasms. Ballance attributed the cause of local spasm of the facial

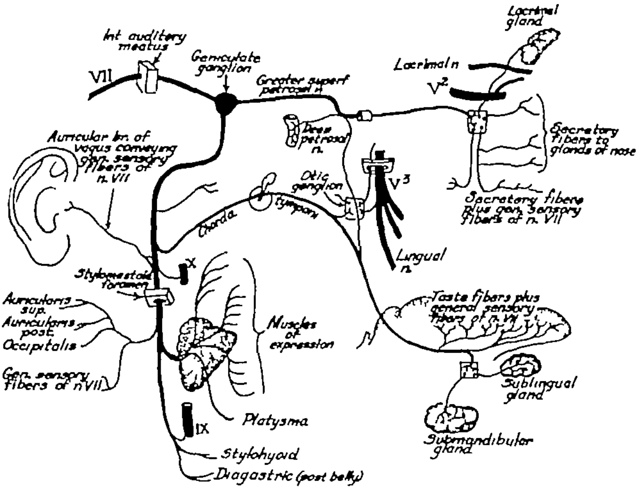


Fig 1064 Scheme of the distribution of the facial nerve (after J C B Grant, 1951)

muscles to a disorder of the cells of the facial nucleus and considered that the spasms are really local epileptic phenomena associated with regressive changes in the cells. Spasmodic movements may also be the result of scar tissue interfering with regeneration of small nerve branches. In extreme cases of facial spasm ("tic douloreux") suppression of facial nerve function may be required to eliminate the spasm (Marino and Alurraldi 1919)

LATE RECONSTRUCTION

Reconstructive operations performed for facial paralysis are of two varieties those that achieve a static improvement by fascia lata or dermal graft suspension and procedures directed toward restoration of movement by muscle transposition a combination of both methods has also been employed

All of these procedures however are palliative The muscles of expression are complex structures. The innumerable fine muscle fibers are capable of independent contraction producing the finely shaded movements of expression these cannot be restored by suspension or muscular transposition The support of the paralyzed side by facial lata slings prevents the displacement of the paralyzed side of the face by the normal musculature of the unaffected side. This operation provides symptomatic relief and improvement of appearance by reestablishing symmetry to the face.

Fascial Suspension

The method of suspending sagging tissues of the face by strips of fascia lata extending between the orbicularis oris and the temporalis or masseter muscles, has been the

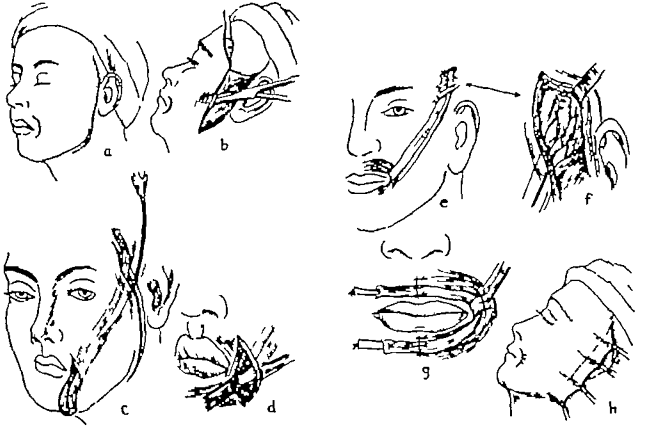


Fig 1065 Fascial suspension for facial paralysis

A. Line of incision permitting exposure of subcutaneous structures.

B. Skin of the face is widely undermined.

C. A fascial strip is passed down beneath the skin and looped around the orbicularis muscle. This procedure is done with the Blair fascia lata needle.

D Illustrating the manner in which the fascial strip is looped around the orbicularis muscle.

E. Fascial suspension in place and anchored to the temporalis muscle.

F The fascial strip is threaded through the fibers of the temporalis muscle and fascia and anchored with sutures.

G Illustrating the method of passing second fascial loop into the lips.

H. The excess skin is excised.

procedure most extensively used (Blair 1926).

The principle employed in all suspension operations is to lift the sagging tissues of the affected side in order to obtain facial symmetry when the unaffected muscles of the other side are at rest. The advantage of anchoring the fascia lata slings into the temporalis or masseter muscles is that a slight amount of voluntary control is obtained through the transmission of slight motion to the fascia lata by the contraction of the muscles It is also usually necessary to remove excess skin on the paralyzed side in facial paralysis of long standing

An incision in the temporal region in front of the ear is extended below and behind the angle of the mandible (Fig 1065*A*) The skin of the face is undermined freely especially in older patients to permit the excision of excess skin (Fig 1065*B*) When a considerable amount of excess skin is present the incision in the preauricular area extends to the level of the lobe of the ear The incision detaches the ear lobe and curves backward into the retroauricular fold posteriorly across the upper third of the mastoid process to the hairline behind the mastoid and downward along the hair line for approximately 3 to 5 cm The skin of the face is raised from the parotid mas-

seteric fascia and undermined anteriorly around the corner of the mouth and lips.

A semilunar incision is then made in the region of the nasolabial fold about 1 cm from the corner of the mouth on the affected side (Fig 1065*A* *B*) The position of the nasolabial fold may be located by upward digital pressure on the corner of the mouth A fold of excess skin in the area of the nasolabial fold is noted in facial paralysis of long-standing It may be necessary to excise an oval segment of skin from this area to remove the fold The long axis of the oval skin segment is parallel to the nasolabial fold the resultant scar thus reproduces the nasolabial fold which is absent in cases of facial paralysis. The simple excision of skin however is inadequate to maintain the corrected deformity and suspension by fascial strips is required to support the functionless tissue

Fascia lata is removed from the thigh by the stripper technique (see Fig 472, Chapter 19) Each fascial strip is divided into numerous narrower strips by the following technique An incision parallel to the direction of the fibers is made at one end of the fascia lata strip 3 to 5 mm. from the edge of the strip the end of the fascial strip is divided into two tongues of tissue one narrow and the other wide a hemostat is applied to the narrow tongue, the wider tongue being held with a gauze compress The narrow tongue is then torn away stripping it from the main fascial graft along the direction of the fibers. This maneuver is repeated to obtain the required number of narrow fascial strips.

A fascia lata strip is brought down from the temporal region with the Blair fascial needle and is looped through the atrophied orbicularis *oris muscle and back to the* temporal region (Fig 1065*C* *D*) The two ends of the strip are anchored to the temporalis muscle by threading them through the muscle bundles and suturing the ends together (Fig 1065*E* *F*)

A second strip of en passed through the loop of the first strip at the corner of the mouth and the ends are carried through the upper and lower lips to a point beyond the angle of the mouth on the unaffected side. Small vertical incisions are made in the mid line of the upper and lower lips to aid in placing the fascia Mattress sutures, placed on the ends of the strip are brought through the skin to anchor the strip (Fig 1065G) the sutures are withdrawn after healing occurs. Alternatively buried sutures of fine chromic catgut may be placed through small skin incisions to anchor the ends of the strips

The procedure which consists of extending the fascia lata strip to encircle the angle of the mouth on the non-paralyzed side should be avoided for it tends to limit the opening of the mouth

Additional strips may be placed to assist *in supporting the cheek* The Blair needle threaded with the strip is introduced deep into the tissues of the cheek The tip of the needle is then rotated outward to pierce the skin surface the fascial strip is withdrawn from the needle The Blair needle is then removed and introduced through the tissues of the cheek immediately under the skin level the tip of the needle is then brought out through the previously established opening in the skin and the fascial strip is again placed into the needle and drawn upward into the temporal region The ends of the fascial loop are sutured into the temporalis fascia The skin of the face is then stretched backward and upward and the excess skin is resected

The ends of *the loops of fascia lata* are anchored to the temporalis fascia by threading them through the eye of a fascial needle which then pierces the temporalis fascia *The ends of the fascial strip are* tied in a square knot and silk sutures are placed through the fascial knot to secure it.

One cannot emphasize too strongly the (rection in fascial suspension by When adequately corrected the ars to be left with a per

petual grin permanent overcorrection does not occur for subsequent sagging of the tissues restores the symmetry of the face

An alternate technique which has produced good results, is to puncture the oral mucosa instead of the skin bringing the fascial loops out through the mouth then reinserting them through the same opening in the oral mucosa. This technique presents the theoretical disadvantage of possible contamination by the oral secretion and consequent infection such infection has not occurred in our cases. The technique has the practical advantage of including the deep structures of the face in the fascial loop

Relaxation of the suspended facial tissues may occur after a number of years requiring exposure and tightening of the fascial slings and excision of excess facial skin.

Dermal Suspension

Dermal grafts may also be employed for suspension of the paralyzed face. A dermal graft is prepared in the manner described in Chapter 19 (see Fig 465) A skin incision is made in the nasolabial fold and a wide sheet of dermis is sutured into the remains of the orbicularis oris muscle. The dermal graft is also anchored to the temporalis fascia by means of interrupted silk sutures after gross overcorrection by traction In paralysis of long-standing, the dermal graft provides the atrophied face with a layer of padding which assists in restoring symmetry with the unaffected side. The suspensory action of the dermal graft, however appears to be less positive than that of the fascial strips.

Muscle Transposition

The principle employed depends upon the restoration of muscular contraction through transposition of a portion of the temporalis or masseter muscles supplied by the fifth cranial nerve, thus grossly replacing facial expression which has been lost due to injury of the facial nerve. Contraction of the muscles of mastication such as occurs in the act of biting causes a simultaneous contraction of the transposed muscle, for example producing a semblance of a smile Considerable self training on the part of the patient is required to produce such simple movements of facial expression For this reason muscle transposition operations should be reserved for young patients older patients are unable to adapt the transposed muscles of mastication to provide motion in the paralyzed face

Flaps of temporalis muscle prepared by incising strips parallel to the muscle fibers have been turned down from the temporal fossa over the zygomatic arch and inserted into the cheeks and the eyelids This procedure with variations, was described in detail by Eden in 1911 In our experience such narrow muscular flaps become inactive probably because of the deficiency of the blood supply due to the kink at the base of the muscle flap and the interruption of the nerve supply in the narrow muscular strips.

In order to preserve the blood supply a sizeable portion of the temporalis muscle with its overlying temporal fascia and the underlying pericranium is turned down, its distal portion being attached near the angle of the mouth by suture to the surrounding tissue or by intermediary fascia lata strips. A portion of the zygomatic arch must be resected in order to permit passage of the muscle The blood supply and a degree of voluntary control of the corner of the mouth are preserved in this manner the type of suspensory action is similar to that achieved with the fascial sling

In the authors experience better results have been obtained by the use of the anterior half of the masseter muscle.

Masseter Muscle Transposition

A preauricular incision is extended downward to the angle of the mandible and forward to a point immediately in front of the anterior border of the masseter muscle. The masseter is exposed through the incision the muscle is divided vertically in its mid portion, and the anterior half of the muscle

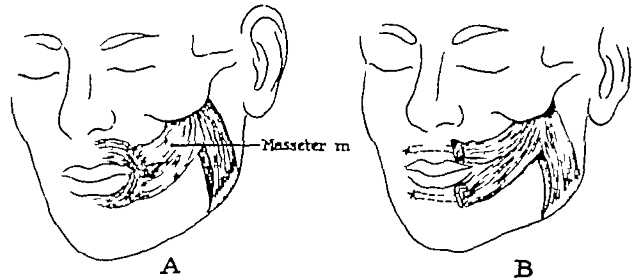


FIG 1066. Muscle transposition for facial paralysis

A. The anterior half of the masseter muscle is moved forward and sutured to the orbicularis oris muscle at the angle of the mouth.

B When the transposed muscle is long enough each divided portion may be sutured into the corresponding lip.

is raised subperiosteally from its mandibular attachment. The external maxillary artery and anterior facial vein are ligated and the skin undermined in the region between the muscle and the corner of the mouth. Care is exercised to avoid damaging Stensen's duct.

The detached anterior half of the masseter is divided vertically for about two-thirds of its length (Fig 1066*A*) The corner of the mouth is then drawn laterally as far as possible and the orbicularis oris is sutured to the masseter (Fig 1066*A*) The divided ends of the masseter if of sufficient length are carried underneath the skin of the lips toward the unaffected side and retained with mattress sutures brought through the skin (Fig 1066*B*) If the muscle is not long enough for this purpose a strip of fascia may be sutured to the masseter muscle and extended across the lips beneath the skin similar to the fascia lata suspension procedure

Combined Suspension and Muscle Transposition

We have used masseter muscle transposition in younger patients and fascia lata suspension in older individuals both techniques have given gratifying results. These two methods may be combined fascial strips are extended from the temporal muscle to the orbicularis oris, and the masseteric flap is attached to the corner of the mouth. Fascia lata suspension provides support and is therefore completed first to adjust the position of the corner of the mouth the masseter muscle flap is then sutured to the corner of the mouth and into the lips as described above

Variations in the technique have been described Bruner (1926) and Adams (1916) advocated exposing the masseter muscle through the intraoral approach McLaughlin (1950) has employed the temporalis tendon detached from the coronoid process, as a means of anchoring fascial strips and of obtaining movement through the contraction of the temporalis muscle

Procedures which utilize masseter muscle transposition are indicated for young patients. The muscular action of the masseter prevents later progressive sagging of the tissues a disadvantage of the suspension operation and also permits some degree of voluntary control of the angle of the mouth

Two cases of facial paralysis corrected by the combined fascia lata suspension and masseter muscle transposition are shown in Figures 1067 and 1068

Postoperative Care

Following fascia lata suspension or muscle transposition, a pressure dressing is applied over the entire side of the face and

A B

Fig 1067

A. Facial paralysis of the left side. Note drooping of the angle of the mouth.
B. Correction obtained by combined fascia lata suspension and masseter muscle transposition.

A B

Fig 1068

A. Facial paralysis of the right side.
B. Result obtained by combined fascia lata suspension and masseter muscle transposition.

maintained in position with a Barton bandage to prevent the patient from moving the jaw. A soft diet is prescribed for a week or ten days.

It is always necessary to occlude the eyelids by means of an eyelid suture to avoid exposure of the cornea and the danger of abrasion under the dressing. Hematoma is prevented by adequate hemostasis. If hemostasis has been inadequate, placing a drain in a dependent position for a period of twenty four hours is an advisable procedure. Postoperative edema is minimized by the use of a carefully applied pressure dressing maintained for a period of two to three days.

The patient does not regain the use of the transplanted masseter muscle until several weeks after operation; during this period physiotherapy employing electrical stimulation and massage may be applied to the face.

Neurotization

Neurotization, or the physiologic phenomenon of the invasion of nerves from the masseter or temporal muscles transplants into the facial muscles, was first advanced by Lexer and Eden (1911).

Erlacher (1914), in an experimental study, demonstrated regeneration of a paralyzed muscle by neurotization. He paralyzed the biceps muscle by severing the musclocutaneous nerve and then implanted flaps from the pectoralis and deltoid muscles into the paralyzed muscle. According to his observations, reactivation of the degenerating muscle occurred as the result of the ingrowth of nerves from the functioning muscles. Other observers have noted movements in adjacent groups of muscles which formerly showed no movement, and movements in muscles located at a distance from the attachment of the transplanted muscle bundles. Owens (1950) has recently revived the hypothesis expressed by Lexer and Eden (1911) and Halle (1933) of the possibility of innervating the paralyzed muscles by the implantation of muscular strips containing filaments of the fifth nerve. These observations may explain the better results obtained in younger patients when the masseter muscle transposition operation is done prior to the degeneration of the facial musculature.

Paralysis of the Frontalis Muscle

Absence of expressive movements of the forehead resulting from paralysis of the frontalis muscle is a deformity because of the contrast between the active and paralyzed sides of the forehead. Drooping of the eyebrow is an additional deformity in facial paralysis of long-standing and a functional impairment which prevents raising the upper eyelid.

Adams (1916) advocated transposing a vertical flap from the unaffected frontalis muscle to the paralyzed side. An incision is made immediately above the eyebrow on the normal side. The frontalis muscle is exposed and a slip of the muscle is raised with the periosteum covering the frontal bone. The muscle flap is stripped upward to the galea aponeurotica, which serves as the pedicle of the flap. The skin of the forehead of the paralyzed side is then undermined. A small incision is made above the eyebrow on the affected side, the muscle flap is transposed by means of guide sutures, and is then anchored to the subcutaneous tissue above the paralyzed eyebrow. Because the muscle slip is denervated, active movements of expression cannot occur, but the transposed muscle serves as a means of suspension for the paralyzed eyebrow. In some cases a degree of function may occur as the result of the contraction of the occipitofrontalis, particularly in individuals with marked activity of this muscle and a mobile galea aponeurotica.

An additional procedure consists in excising an ellipse of skin from above the drooping eyebrow in order to raise it to the proper level. The scar is dissimulated at the junction of the eyebrow with the forehead skin.

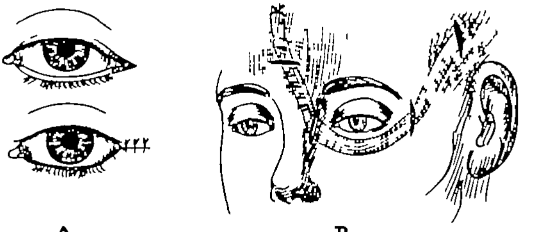
EPIPHORA IN FACIAL PARALYSIS

Persistent epiphora is often the major complaint of patients with facial paralysis Paralysis of the lower eyelid results in exposure of the eyeball and danger of corneal ulceration and subsequent scarring It also causes epiphora due to the eversion of the eyelid margin and because the punctum is no longer applied against the eyeball.

The tears secreted by the lacrimal gland spread over the palpebral fissure by surface tension and form a tear lake at the lateral canthus a tiny stream like flow extends to the medial canthus. Secretion from the tarsal glands assists in preventing the tears from flowing over the edge of the lower eyelid. The action of the orbicularis oculi muscle assists the lacrimal sac to collect the tears. The lacrimal portion of the muscle is attached to the fascia covering the lacrimal sac when the muscle contracts it exerts a pull on the fascia thus dilating the sac. *It also shortens and widens the lower cana*liculus and inverts the punctum. This process occurs each time the patient blinks Most of the tears appear to be collected by the lower punctum and are evacuated through the lower canaliculus. After reaching the lacrimal sac, the tears pass down into the nose by capillary action the force of gravity and the contraction of the sac.

Epiphora in facial paralysis occurs for a variety of reasons the paralyzed orbicularis oculi muscle cannot dilate the lacrimal sac, due to the relaxation of the eyelid the punctum is not in contact with the eyeball and is often stenosed the caruncle which is exposed by the lagophthalmos becomes hypertrophied the main tear lake lies in the middle of the sagging lid and away from the canthi (McLaughlin 1950) there may be increased lacrimal secretion due to exposure of the eye from lagophthalmos and ectropion Interference with normal drainage leads to an increased loss of tears by evaporation thus the need for increased *activity of the lacrimal gland.*

Relief of epiphora in facial paralysis may be obtained by a variety of operative procedures (1) by providing support to the flaccid cheek as previously described, thereby releasing the pull of the cheek on the lower lid (2) by suspension of the lower eyelid by a strip of fascia lata (3) by lateral or medial canthoplasty and (4) by dilatation of the lacrimal punctum and slitting the canaliculus.



A B

Fig 1069

A. Lateral tarsorraphy The free margins of the eyelids are excised in their lateral portion and sutured together This procedure *diminishes the length of the palpebral fissure, reapplying the lower lid against the eyeball.*

B. Fascial suspension of the lower lid by a strip extending hammock-like from the frontalis muscle on the unaffected side to the temporal muscle on the paralyzed side.

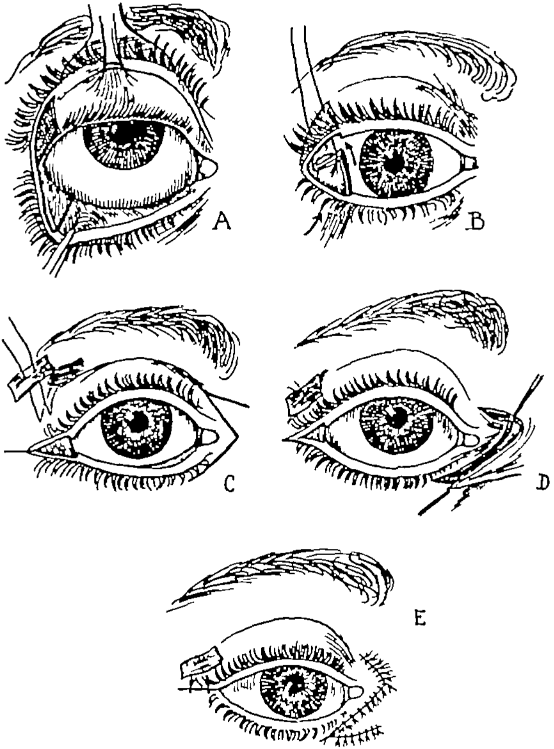


FIG. 1070. Lateral tongue and groove canthoplasty and medial Z-flap canthoplasty

A. Outline of incisions and removal of a section of tarsus and conjunctiva from the upper eyelid

B. Traction is exerted upon the tarsoconjunctival flap from the lower eyelid by means of a mattress introduced through the upper eyelid.

C. Completion of lateral tongue and groove canthoplasty. Outline of medial canthoplasty

D. Transfer of flap from the upper to the lower eyelid in medial canthoplasty

E. Lateral and medial canthoplasties completed.

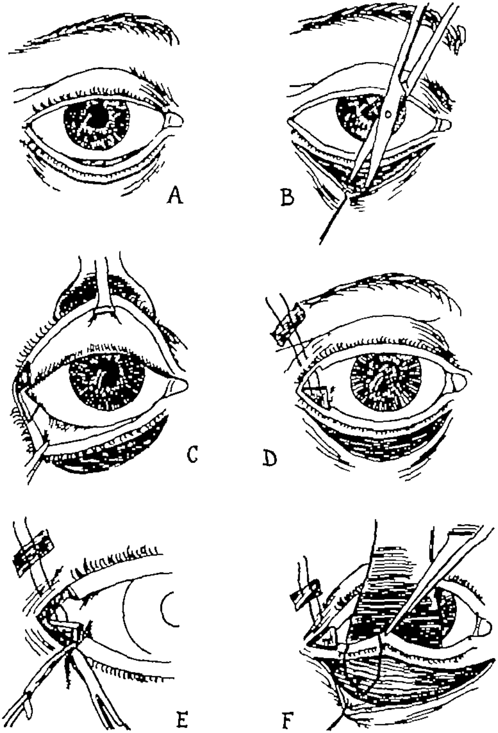


FIG. 1071 Lateral tongue and groove canthoplasty combined with excision of full thickness lower eyelid tissue.

A. Skin incision below eyelid margin.
B Raising eyelid skin from orbicularis oculi muscle fibers.
C. Outline of lateral tongue and groove canthoplasty
D Mattress suture placed for tongue and groove canthoplasty
E. Eyelid margins excised for additional surface contact between the lids.
F Outline of trapezoid segment to be excised.

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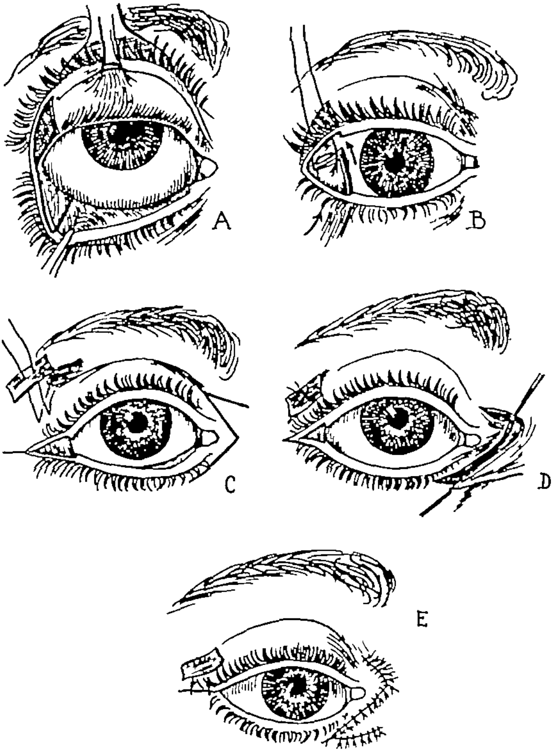


FIG. 1070. Lateral tongue and groove canthoplasty and medial Z flap canthoplasty

A. Outline of incisions and removal of a section of tarsus and conjunctiva from the upper eyelid

B. Traction is exerted upon the tarsoconjunctival flap from the lower eyelid by means of a mattress introduced through the upper eyelid.

C. Completion of lateral tongue and groove canthoplasty. Outline of medial canthoplasty

D. Transfer of flap from the upper to the lower eyelid in medial canthoplasty

E. Lateral and medial canthoplasties completed.

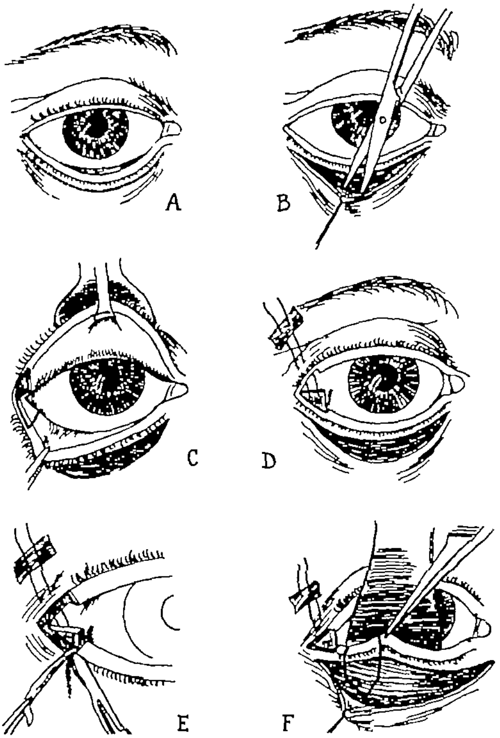


FIG 1071 Lateral tongue and groove canthoplasty combined with excision of full thickness lower eyelid tissue.

A. Skin incision below eyelid margin.
B. Raising eyelid skin from orbicularis oculi muscle fibers.
C. Outline of lateral tongue and groove canthoplasty
D. Mattress suture placed for tongue and groove canthoplasty
E. Eyelid margins excised for additional surface contact between the lids.
F. Outline of trapezoid segment to be excised.

(*Continued in next figure*)

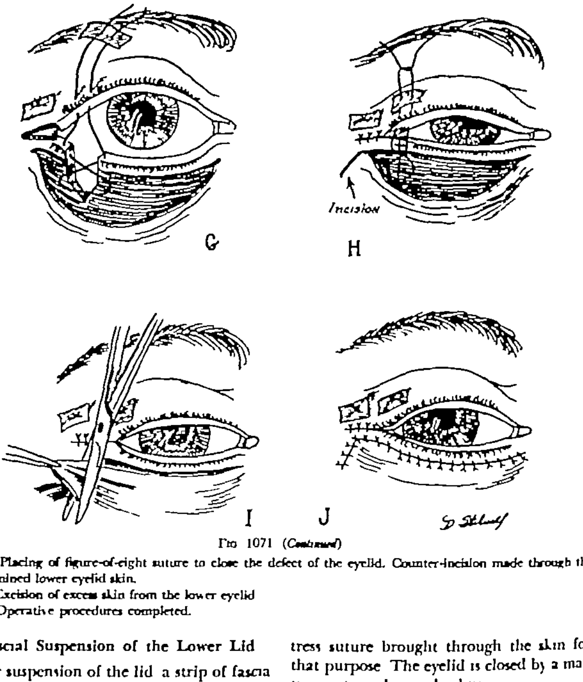


Fig 1071 (*Continued*)

G Placing of figure-of-eight suture to close the defect of the eyelid. Counter-incision made through the undermined lower eyelid skin.

I Excision of excess skin from the lower eyelid

J Operative procedures completed.

Fascial Suspension of the Lower Lid

For suspension of the lid a strip of fascia is slipped beneath the skin in the temporal region attached to the temporalis muscle and then extended beneath the skin of the lower eyelid to the side of the nose and upward to the frontalis muscle on the unaffected side (Fig 1069*B*) One incision is made on the side of the nose to facilitate placement of the fascia another is made through the skin of the forehead where the fascia is attached to the frontalis muscle The strip is anchored by a buried suture the end of the strip is carried upward for a short distance and maintained with a mattress suture brought through the skin for that purpose The eyelid is closed by a mattress suture during healing

Canthoplasty

Lateral canthoplasty is a routine operative procedure in facial paralysis of long standing

The simplest technique of lateral canthoplasty is lateral tarsorraphy which consists of dividing a suitable length of the margin of each eyelid in its lateral portion and approximating the raw surfaces by means of a mattress suture (Fig 1069*A*)

A technique of canthoplasty which pro-

vides a more positive support of the lateral portion of the lower eyelid is the following A triangle of tarsus and conjuntiva is excised from the upper eyelid immediately medially to the lateral canthus (Fig 1070*A*) a flap of conjunctiva and tarsus is outlined in the lower eyelid (Fig 1071*A*) freed from the skin muscle layers and advanced into the defect on the inner aspect of the upper eyelid (Fig 1070*B*). A mattress suture inserted through the margin of the lower lid flap transfixes the upper lid through the skin (Fig 1070*B*) The suture ends are then brought through the skin of the upper lid and tied over a small piece of rubber dam or gauze (Fig 1070*C* *D*)

Lateral canthoplasty may be combined with a modified Kuhnt-Szymanowski operation with resection of skin from the lower lid. The excision of a V-shaped segment of the eyelid is required in long-standing sagging of the lid The V shaped segment may be removed either from the center of the lid or in its lateral half (Fig 1071)

Lateral canthoplasty assists in replacing the eyelids against the eyeball it also reduces the width of the palpebral fissure usually enlarged in these cases

Medial canthoplasty provides support for the medial portion of the lower eyelid, bringing the lower punctum into a more favorable position against the eyeball

A Z plasty procedure (Fig 1070*C* *D* *E*) transposing a triangular flap of skin from the upper eyelid into the lower eyelid and producing medial traction on the medial canthus may be employed in conjunction with a lateral canthoplasty

Medial canthorraphy or denudation of the margins of the canthal portions of both upper and lower eyelids and suturing the raw surfaces in apposition by means of a mattress suture is an additional procedure. A more positive result is obtained by the medial canthoplasty technique described in Chapter 21 (see Fig 592)

Dilatation of the Punctum and Slitting of the Canaliculus

Dilatation of the punctum is of temporary benefit only In most cases a dilatation and slitting of the full length of the canaliculus is necessary This is followed by a vertical cut on the conjunctival surface of the lid down to the ampulla and a third cut horizontally to meet the original slit (see Fig 591 Chapter 21) thus achieving a triangular excision of the roof and posterior wall of the canaliculus (McLaughlin 1950) The new ostium thus lies close to the lacrimal sac, establishing a short and direct passageway through which the tears must travel Stallard (1950) is opposed to slitting the canaliculus to the medial canthus because it displaces the entrance to the lacrimal system away from its correct location near the bulbar conjunctiva. The opening is overhung by the caruncle when the canaliculus is slit to the medial canthus. The gutter of the slit canaliculus may become choked with mucopus and debris. Reconstruction of the canaliculus is not possible later if occlusion of the canaliculus occurs. The caruncle which becomes greatly enlarged in some cases is reduced in size by diathermy-coagulation

28

DEFORMITIES OF THE EXTERNAL EAR

DEFORMITIES OF THE AURICLE

The auricle or pinna formed by skin and cartilage oval in shape is dependent upon its cartilaginous framework for contour and support in its upright position The anterior third of the auricle is attached to the skull the posterior two-thirds are free from the cranium forming varying angles of separation from it. The auricle presents a number of prominences and depressions the concha antihelix and helix tragus and antitragus (Fig 1072) The auricle is prolonged downward by the lobe of the ear and inward by the external auditory canal The skin thin and soft, is intimately attached over the surface of the cartilage except along the helix border where it is loosely attached The blood supply to the auricle is abundant (Fig 1073) the arterial supply accounting for the reattachment of a portion of the auricle after almost complete severance of the external ear (Fig 1074)

Deformities of the auricle without loss of tissue are usually due to faulty approximation of full thickness lacerations of the helix usually resulting in distortion and notching of the heilx border Deformities due to loss of skin or cartilage result in distortion due to scar contracture (Fig 1075) and occur most frequently around the periphery of the helix and lobe Loss of aricular cartilage alone is usually the result of exposure of the cartilage by the destruction of the covering skin as in a burn for example Loss of postaural skin creates adhesions between the auricle and the skull Loss of skin from the outer surface may cause forward folding of the auricle (Fig 1075) Stenosis of the external auditory canal may be due to burns or wounds.

Full thickness loss of tissue may involve either a small or large portion of the auricle Burns result in deformities which vary from minor defects such as the thinned helix border (Fig 1076) to subtotal loss of the auricle.

Complete traumatic loss of the auricle is an unusual occurrence (see Fig 1088) for the lobule a portion of the concha and the external auditory canal are usually preserved even in cases of severe injury

DEFORMITIES WITHOUT LOSS OF TISSUE

Irregularities in contour due to faulty approximation are corrected by excising the scar and approximating the cut sections of the cartilage and skin covering The techniques of Z plasty stepping halving or dovetailing the edges of the cartilage and soft tissue wound prevents recurrence of a notched helix border

Otohematoma "Cauliflower-ear"

A condition most frequently observed in pugilists this type of deformity is caused by hemorrhage resulting from a direct blow or excessive traction on the auricle Blood collects between the perichondrium and cartilage and the clot becomes fibrosed causing a thickening which obliterates the convolutions of the auricle This process is similar to that which produces thickening

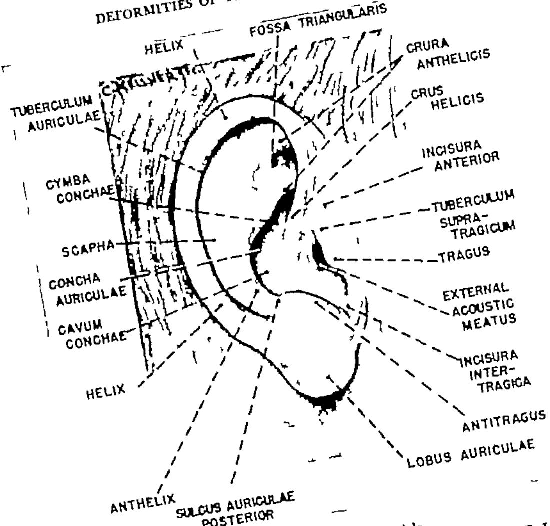


FIG 1072. Diagram of the auricle

(From Applied Anatomy of the Head and Neck H. H. Shapiro, 1947 2nd Ed. J B. Lippincott.)

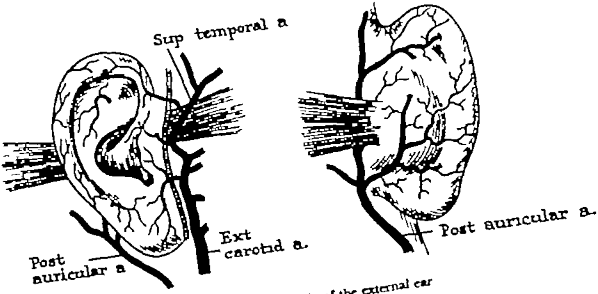


FIG 1073 Blood supply of the external ear

A. Anterior view
B. Posterior view

FIG. 1074

A and B. Laceration with a razor through the upper part of the auricle which remains attached only by a small anterior skin pedicle.

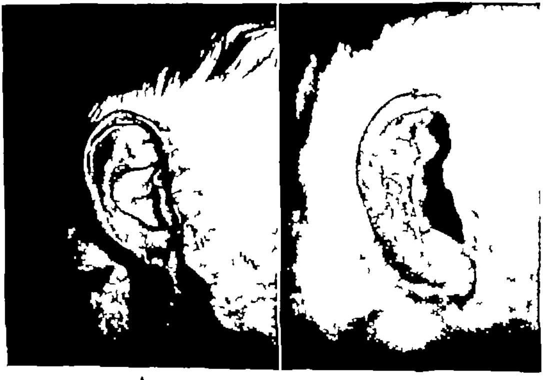
C and D. Four days later. Survival of the severed portion after suture.

A B

FIG 1075

A. Contracture of the auricle caused by the loss of skin due to burn.

B. Correction consisted of excising the scar tissue over the outer surface of the auricle and covering the resultant raw surface with a skin graft, immobilized by a dental compound mold



A B

FIG 1076. Thinned helix border due to burns

A Thinned ear resulting from gasoline burn.

B. Result obtained by mobilization of the auricular skin as shown in Figure 1078.

Fig 1074

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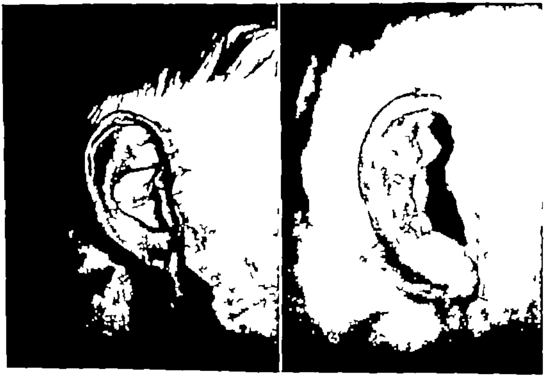


A B

FIG 1076 Thinned helix border due to burns

A. Thinned ear resulting from gasoline burn.

B. Result obtained by mobilization of the auricular skin as shown in Figure 1078.

of the septal cartilage which is also a frequent lesion in boxers

Early preventive treatment, after hematoma has occurred requires incisions for drainage of the blood or blood clots and serum A molded pressure dressing should be applied to prevent recurrence of the hematoma softened dental compound can be molded into the folds of the auricle pledgets of moist cotton may also be employed

Late treatment of the cauliflower ear deformity consists in carving out the thickened tissue in order to improve the contour of the auricle Exposure is obtained by raising skin flaps through carefully placed incisions and applying a pressure dressing which assures coaptation of the soft tissues to the cartilaginous framework and also prevents hematoma

STENOSIS OF THE EXTERNAL AUDITORY CANAL

The concha is prolonged inward by the external auditory canal through an opening, the meatus. The canal which is lined with skin is directed horizontally and slightly forward and is supported by a fibrocartilaginous framework in its lateral portion and by a bony framework in its medial portion which terminates at the tympanum

Lacerations may penetrate the external auditory canal When the concha has been destroyed by traumatic avulsion or burning and only the cut end of the external auditory canal remains, there is a tendency for the peripheral scar to close the auditory meatus. Lacerations within the external auditory canal also tend to cause stenosis. Cuts involving the canal should be carefully sutured whenever possible and the canal should be kept packed tightly during the healing period A small prosthetic appliance should be prepared taking an impression with dental compound and making a mold in acrylic. The tendency for stenosis disappears after three or four months and the wearing of such a prosthetic support during this period minimizes the danger of stenosis.

Cicatricial stenosis of the external auditory meatus and canal is remedied by a series of V-shaped incisions as recommended by Steffensen (1946) when the skin lining the canal is not too badly scarred In severe stenosis when the meatus is completely closed and the canal filled with scar tissue the cicatricial tissue must be excised. The

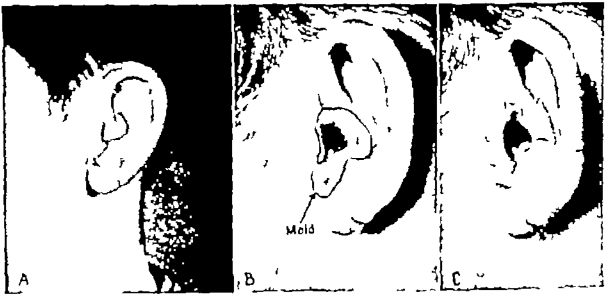


Fig 1077 Traumatic stenosis of the external auditory canal

A. Shows closure of external auditory meatus resulting from laceration

B. Acrylic mold worn after skin grafting

C. Result obtained the canal remains patent

skin defect is repaired by means of the epithelial inlay technique Two impressions of the canal are taken with dental compound. One impression serves to maintain a split thickness graft the other impression is duplicated in clear acrylic. The acrylic mold should be worn by the patient for a period of three or four months to counteract the tendency for secondary contraction and stenosis (Fig 1077) A detail in technique is to prepare the mold in such a manner that it fits over the concha this precaution insures the stability of the prosthesis

DEFORMITIES WITH LOSS OF TISSUE

These result from loss of skin cartilage or full thickness of the auricle

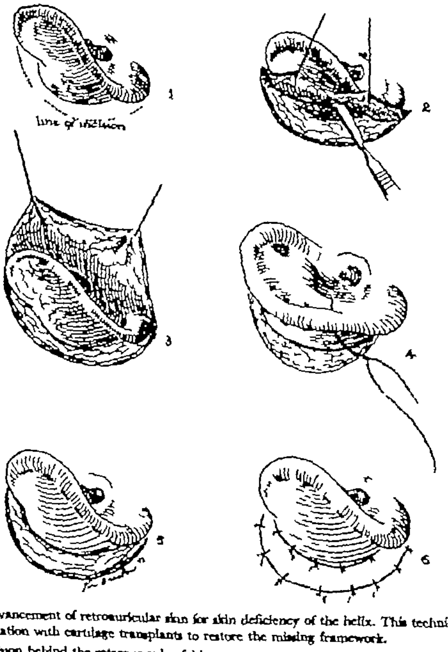


Fig. 1078. Advancement of retroauricular skin for skin deficiency of the helix. This technique can be employed in combination with cartilage transplants to restore the missing framework.

1 Line of incision behind the retroauricular fold.
2. Retroauricular skin raised.
3. The cartilaginous ear framework is exposed.
4 The retroauricular skin has been advanced forming a new helix border the advanced skin is immobilized with vertical mattress sutures.
5 Postauricular defect caused by the advancement of the skin.
6. The defect is covered with a skin graft.

Loss of Auricular Skin

The first choice of a donor site for skin to replace the skin of the auricle is the post auricular area of the unaffected ear

In deformity with moderate loss of skin such as that observed following a burn the external ear appears thinned although with little loss of cartilage (Fig 1076) Repair is accomplished by advancing the retroauricular skin (Fig 1078) An incision is made behind the the retroauricular fold and the skin over the medial aspect of the auricle is dissected from the cartilage the dissection is extended to the helix border and includes a portion of the lateral aspect of the auricle (Fig 1078-3) The skin on the medial aspect of the auricle is advanced to its lateral surface Vertical mattress sutures immobilize the advanced skin (Fig 1078-4) If the deformity is unilateral the retroauricular defect is covered by a full thickness graft from behind the unaffected ear if bilateral a split thickness graft is obtained from another donor site (Fig 1078-5 6)

If the skin in the postaural area cannot be used because of burn scars, for example, the helix border is reconstructed by thin tubed pedicled flaps raised from the pre auricular cervical or supraclavicular areas (see Figs. 1106 and 1107) When larger size tubed flaps are required a vertical tubed pedicle is raised along the hairline in female patients where the resultant scar can be hidden by the hair (Fig 1079*A*) In male patients, a horizontal tubed pedicle is removed from below the hair bearing area of the neck and the collar line where the resulting scar is not conspicuous (Fig 1079*B*)

Skin grafts are employed to free the auricle from adhesions due to scars in the postauricular region or to supply skin to the anterior surface of the auricle when

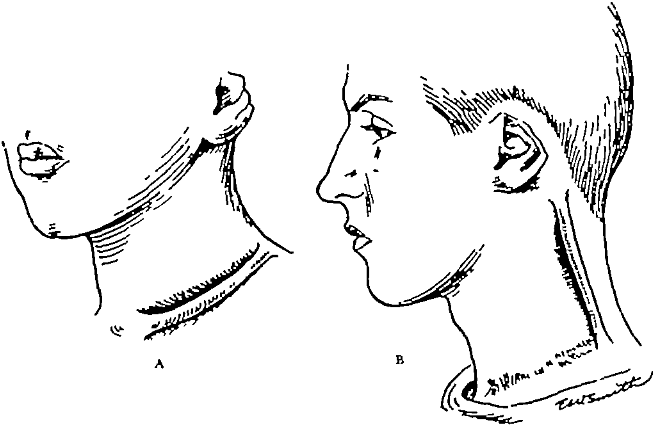


Fig 1079 Examples of fine tubed pedicled flaps employed for restoration of the helix border

A. Horizontal flap below the collar line and hair-bearing area of the neck, in males

B Vertical flap immediately anterior to the hairline in females

the latter is folded upon itself (see Fig 1075) To correct this condition an incision is made along the entire border of the helix 1 cm. from the edge of the border and the cartilage is exposed and diced in order to flatten it A skin graft is placed over the resulting raw area and a dental compound mold is applied to the outer surface of the auricle.

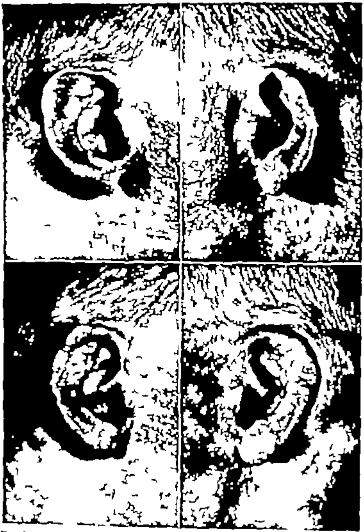
In some cases of burns, the auricle is buried beneath the scar tissue and adheres to the skull this condition is usually limited to the concha and antihelix or to the concha alone The cartilage is freed by an incision around the border of the helix the scar tissue is then excised. Skin grafts, when required are applied to the retroauricular and lateral aspect of the auricle the graft is immobilized by a dental compound mold.

Loss of Auricular Cartilage

Loss of auricular skin and a portion of the helix by burning as seen in the patient shown in Figure 1080 may be satisfactorily repaired by the procedure illustrated in Figure 1078 the cartilaginous defect is repaired by autogenous cartilage which has been carved to shape The cartilage graft is maintained attached to the remaining helix by preparing a flange which overlaps the posterior aspect of the helix stump and is anchored to the auricular cartilage by

A

B



C

D

FIG 1080. Loss of helix due to burns caused by steam from the exploded boiler of a derailed locomotive.

A. Loss of helix border (right ear)

B. Partial loss of the auricle (left ear)

C and D Reconstruction by advancement of postauricular skin as shown in Figure 1078 with restoration of missing framework with carved autogenous rib cartilage.

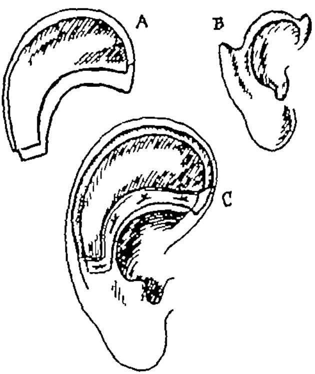


Fig 1081 Attachment of cartilage graft to the stump of the auricular cartilage.

A and B Carved cartilaginous transplant and auricular stump.

C Attachment of transplant to the auricular stump by mattress sutures.

mattress sutures of chromic catgut or fine stainless steel wire sutures (Fig 1081)

When the skin covering the auricular cartilage is avulsed or destroyed by a burn and the cartilage is exposed the major part of the cartilage may be lost by spreading perichondritis. The auricle loses its upright position becoming a mass of retracted and crumpled soft tissue Replacement of a cartilaginous framework between the cutaneous layers of the auricle is possible only after adequate stretching of the crumpled soft tissue The technique of the reconstructive procedures required in this type of deformity is described later in this chapter (see Fig 1087)

Full Thickness Loss of the Auricle

Reconstruction of full thickness loss of a portion of or the entire auricle is always a complex problem for a framework of cartilage covered on each side by skin must be provided. Satisfactory repair is often feasible in small defects of the auricle when the major portion of the auricle is destroyed reconstruction is always difficult.

The Development of Reconstructive Surgery of the Ear

In the Sushruta Samhita there is a passage which refers to the technique of reconstructing the lobe of the ear by means of a flap *taken from the cheek Tagliocozzi (1597)* described the preparation of a flap from the arm for transplantation to the region of the defective auricle (Gnudi and Webster 1950) He gives no details about the separa*tion of the flap from the arm nor of the* possible doubling of the flap upon itself in order to reproduce the two cutaneous layers of the auricle Tagliocozzi cites the case of a monk whose ear was marvelously restored but doubts have been cast on the validity of Tagliocozzi's statement according to Bouisson (1870) "the surgeon from Bologna wrote this narration in an hour of enthusiasm Ambroise Paré (1575) does not discuss the possibility of reconstructing the ear in his surgical treatise but describes the technique of primary suture of the lac*erated auricle warning against placing su*tures through the cartilage for fear of causing perichondritis.

Interest in ear reconstruction was stimulated in the nineteenth century by a case *described by Dieffenbach (1815)* The patient a young man 27 years old was involved in a fight in a public place A police officer who had been summoned removed the upper portion of the auricle with a stroke of his saber The patient was admitted to the Charité Hospital in Berlin where he was treated until primary heal*ing of the wound occurred. Dieffenbach* then undertook to reconstruct the auricle He made an initial incision in the skin of *the mastoid area around the auricle* parallel to the cut surface of the ear two ad*ditional incisions* were then made at right angles to the first outlining a flap with its

pedicle attached to the edge of the auricular defect. Three weeks later he detached one end of the flap folding the remainder of the flap on itself to restore the posterior surface of the new auricle.

Roux (1854) stated that his contemporaries considered the reconstruction of the auricle a surgical impossibility 'Where would one obtain all the skin necessary to form a new ear? He further asked how one could possibly reproduce the resilient auricular cartilage and its complicated convoluted shape He concluded that a prosthesis should be used in cases of total destruction of the ear

Pierce (1930) demonstrated a satisfactory ear reconstruction establishing the principle of using a cartilage graft to provide a framework for the new auricle.

Efforts were made by other surgeons to improve the shape of the reconstructed ear by means of a framework more closely resembling the auricular cartilage. Gillies (1937) employed auricular cartilage removed from the patient s mother and his early results appeared encouraging Fresh and preserved cartilage homografts from unrelated donors and bovine cartilage heterografts were also employed (O Connor and Pierce) 1938 Kirkham, 1940 Converse, 1942 Lamont, 1944 Brown Cannon Lischer Davis and Moore 1947 Gillies and Kristensen, 1951 Steffensen 1952)

These cartilage homografts and heterografts became softened and disintegrated over a period of years in a high proportion of cases and the reconstructed auricle lost its upright position sagged and sculptural details of the framework were effaced (Gibson and Davis, 1953 Schofield 1953 Steffensen, 1955 Cannon 1957)

It is now generally recognized that only autogenous cartilage is capable of furnishing a permanent auricular framework.

Peer (1943 1944 1948) developed a technique permitting the prefabrication of the auricular framework by fragmented pieces of autogenous costal cartilage placed in a mold in a preliminary stage The mold and cartilage are stored in a subcutaneous pocket in the abdomen until the fragments become joined by connective tissue, forming a new auricular framework. The work of Peer emphasized the need for a suitably shaped cartilaginous framework a point also stressed by Conway Neumann, Gelb Leveridge and Joseph (1948)

Because of the multiplicity of operations, the frequent complications and the poor esthetic results often obtained, many surgeons were prone to advise the use of a prosthetic ear rather than submit the patient to surgery An auricular prosthesis, however is not a panacea. Although the immediate result is usually good the prosthesis requires replacement periodically for it loses its color and texture it may cause skin irritation the patient in some cases dislikes the artificial part and fears that it will drop in the soup One of the most difficult problems associated with an auricular prosthesis is the change of the patient s skin color due to exposure to the sun Auricular prostheses in children are not practical Artificial ears should be reserved for inoperable cases and older individuals The attachment by means of surgically created subcutaneous tunnel (Ombrédanne, 1956) appears to provide a more stable anchorage of the prosthesis.

Internal prostheses of inert metals acrylics and polyethylene have also been employed. On the basis of our knowledge of the fate of these materials in other sites, it seems improbable that they can offer satisfactory permanent results in a particularly precarious position such as the auricle

It must be emphasized that after failure due to absorption of a homograft or elimination of an inert substance, not only is the surgeon "back at zero having imposed an entire series of operations upon the patient but the reconstructed auricle has become a crumpled mass of scarred soft tissue, often an insurmountable handicap

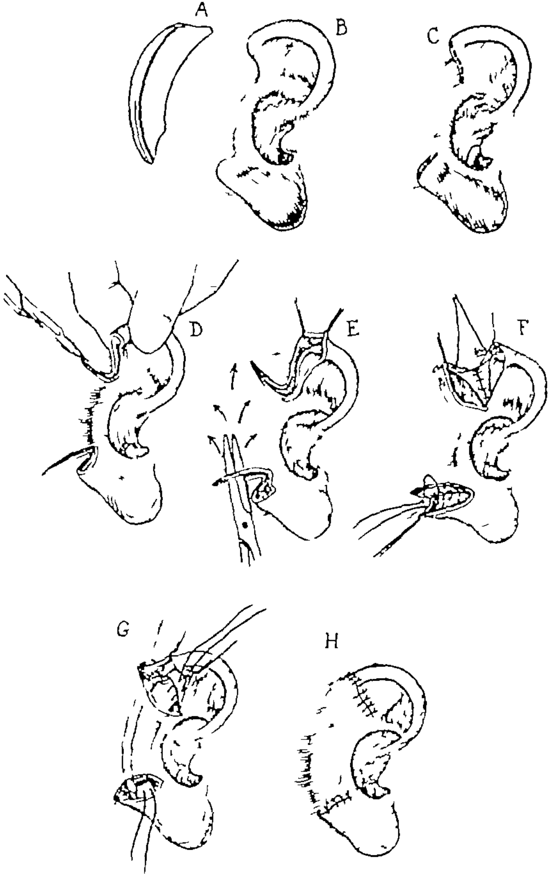


FIG. 1082 Repair of a partial defect of the auricle

A. Diagram of carved costal cartilage graft

B. Diagram of the defect of the auricle

(Legend continued on next page)

Partial Defects of the Auricle

In traumatic defects of the ear the adjacent portions of the ear are contracted toward the defect, which appears to be smaller in size than the true defect the remaining portions of the auricle are deformed as the result of the contraction It is usually necessary therefore to replace the remaining portions of the auricle in correct anatomic position to obtain the size of the true defect. The scar tissue is resected, the defect is opened the portions of the auricle on each side of the defect are replaced in their proper positions. In some cases the contraction causes a curling of the cartilage requiring correction by means of an operative procedure of the type employed for the repair of the protruding ear deformity

Two oblique incisions delimit the upper and lower limits of the defect on the postaural skin. The edges of the cut sections of the remaining portions of the auricle are then sutured to the margins of these oblique incisions (Fig 1082) A carved cartilaginous transplant is placed beneath the skin situated between the two oblique incisions (Fig 1082G H) The cartilaginous transplant must be joined to the remaining conchal cartilage

After an interval of approximately two months, a curved incision is made at a distance from the posterior edge of the cartilaginous transplant which is raised from the subjacent postauricular tissues Care is taken to include a layer of subcutaneous tissue over the cartilage. This precaution is necessary for skin will not survive over denuded cartilage. A split thickness graft covers the defect behind the cartilaginous transplant and over the mastoid area.

Smaller defects of the helix may be repaired by the following technique (Fig 1083) The auricle is pressed against the mastoid area and an ink line is drawn on the skin in this area, the line being parallel and adjacent to the edge of the auricular defect (Fig 1083*A B C*) Incisions are made through the skin along this ink line and also through the edge of the auricular defect (Fig 1083*D*) The posterior edge of the auricular incision is sutured to the anterior edge of the mastoid skin incision (Fig 1083*E F*) A carved costal cartilage transplant is then placed in the soft tissue bed and is joined to the edges of the cartilaginous defect (Fig 1083G *H*) The skin over the mastoid, which has been undermined, is advanced to cover the cartilaginous transplant, and the edge of the skin flap is sutured to the edge of the auricular skin (Fig 1083*I*) A period of healing and vascularization of two or three months is permitted to elapse. During this period a cutaneous tunnel behind the auricle must be cleaned with cotton-tipped applicators Because of this special aspect this procedure may be referred to as the "tunnel procedure" The auricle is detached in a second stage and the resulting elliptical raw areas are grafted with full thickness retroauricular skin from the opposite ear one on the auricle and the other on the mastoid area (Fig 1083*J*) Figures 1084 1085 and 1086 illustrate patients with auricular defects repaired by this technique.

The employment of composite grafts from the opposite ear available when the

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C. Outline of incisions through the margins of the defect.

D The incisions through the edge of the auricular defect are prolonged backward through the skin of the mastoid area.

E. The skin of the mastoid area is undermined between the two incisions.

F The posterior edge of the incision at the border of the auricular defect is sutured to the upper edge of postauricular incision. A similar type of suture is done at the lower edge of the defect.

G The cartilage graft is placed under the skin of the mastoid area and anchored to the auricular cartilage by means of catgut sutures.

H. Suture of the skin incisions.

(Figs. 1082 to 1083 from J M. Converse, Plast. & Reconstruct. Surg., *22* 150 230, 1958)

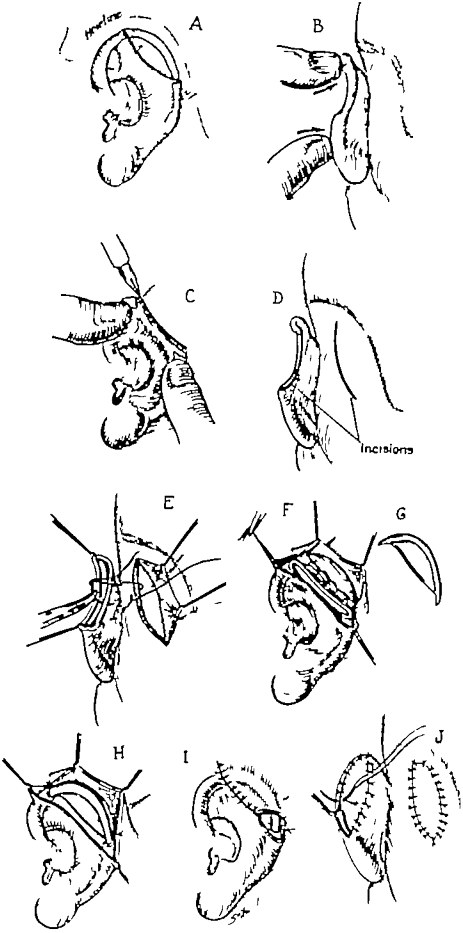

Fig 1083 Repair of a partial defect of the auricle by the tunnel procedure

A Outline of the portion of ear to be restored

B. The auricle is pressed against the mastoid

(*Legend continued on next page*)

auricle is large and protruding (Day 1921 Adams, 1955 Pegram and Peterson 1955) deserves a wider use in the treatment of auricular defects of moderate size.

The tunnel procedure may also be employed in the repair of the shrivelled auricle resulting from loss of the cartilaginous framework. A curved incision is made near the hairline (Fig 1087*A*) an additional incision is made near the border of the helix but on the medial aspect of the auricle (Fig 1087*B*) This precaution is necessary to elongate the soft tissues of the auricle. A cleavage plane is sought and the lateral and medial cutaneous layers are separated (Fig 1087*C*) The lower margin of the postauricular skin is sutured to the lower edge of the hairline incision (Fig 1087*D, E*) and the remaining edge of skin of the auricle is sutured to the upper edge of the hairline incision (Fig 1087*F G*) A period of a number of months should elapse before attempting to place a cartilaginous framework between the cutaneous layers This delay is required to permit softening of the scar tissue and revascularization of the area. A further delay is allowed before separating the cartilage-supported auricle from the mastoid area and skin grafting the retroauricular defect.

Subtotal or Total Loss of the Auricle due to Trauma

Loss of a major portion of or the entire auricle may occur as a result of the ear being cleaved off by a razor slash flying glass a gunshot wound flame or radiation burn or surgical excision. In the patient shown in Figure 1088 the auricle was avulsed under unusual circumstances The patient, a house painter was standing on a scaffold with one of his coworkers. In the course of an argument the patient's left ear was seized by the teeth of his oponent and was totally avulsed remaining between the teeth of the agressor when the patient was precipitated from the scaffold. The avulsed auricle unfortunately was not recuperated

The quality of the skin in the auricular area varies in traumatic defects When amputation of the auricle is due to a clean cut laceration the area is covered by unscarred healthy and supple skin which may be utilized. If the auricle has been avulsed or destroyed by a burn or a gunshot injury the area may show multiple linear or surface scars and the scarred area must be excised and replaced by a skin graft. Scarred skin resulting from the healing of partial thickness burns may be of sufficiently good quality and not require skin grafting

Reconstruction of the auricle in traumatic defects is relatively more feasible than that of the congenitally absent ear for usually portions of the concha and the external auditory canal are present. The ear lobe however may require reconstruction.

When a large part or almost the entire auricle has been destroyed a number of obstacles must be surmounted in successive stages. These include (1) a suitable skin covering devoid of hair follicles, (2) a framework of cartilage to maintain the upright position of the reconstructed auricle and reproduce the characteristic convolutions of the external ear and (3) a covering of skin for the posteromedial aspect of the auricular framework after it is raised from the mastoid area The ear lobe may also require reconstruction A number of additional retouch

C An ink outline is traced on the skin of the mastoid, parallel to the edge of the auricular defect.
D Outline of incisions to be made along the edge of the defect and through the skin of the mastoid area.
E Suture of the posterior edge of the auricular incision to the anterior edge of the mastoid incision.
F Suture has been completed.
G Diagram of the costal cartilage graft.
H The costal cartilage graft has been implanted.
I The skin of the mastoid area is advanced to cover the cartilage graft.
J In a second stage, the auricle is separated from the mastoid area and full thickness retroauricular grafts from the opposite ear are employed to cover the defects.

ing operations is usually necessary in order to achieve satisfactory contour of the reconstructed auricle

THE SKIN COVERING The transplanted auricular framework must be covered with healthy skin devoid of hair follicles Because the hairline of the scalp normally descends to a point situated below the highest portion of the helix border of the normal auricle the upper portion of the transplanted cartilaginous framework will be covered by scalp Two techniques may be employed to replace the hair bearing tissue. The first consists of implanting the cartilage

FIG 1084 Defect of the upper portion of the auricle the result of a burn

A. Preoperative appearance

B. Result obtained by technique illustrated in Figure 1083

A B

FIG 1085 Defect of the upper portion of the auricle the result of a burn

A Preoperative appearance

B Result obtained by technique illustrated in Figure 1083

Fig 1086 Reconstruction for partial loss of the external ear

A. Photograph shows loss of the upper half of the left ear as a result of a dog-bite in childhood.

B. Result obtained after implantation of framework of autogenous costal cartilage and skin grafting according to the technique illustrated in Figure 1098.

C. Front view showing defect.

D Front view showing reconstructed ear

E. Posterior view showing defect.

F Posterior view showing reconstructed ear

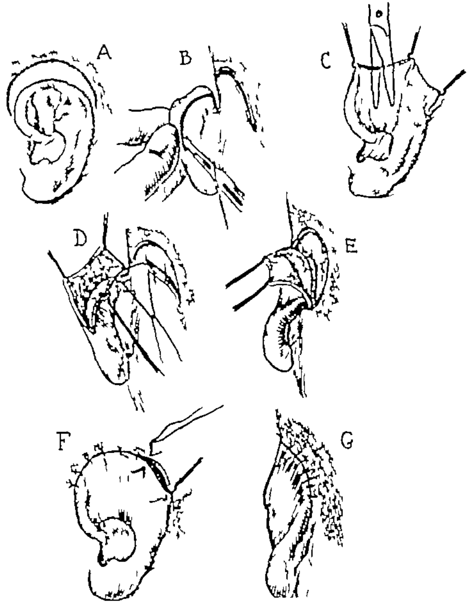
A
B
C
D
E
F
G

FIG 1088

A. Loss of the auricle as a result of traumatic avulsion by a human bite.
B. Result obtained by surgical reconstruction.
C. Close-up view of the reconstructed ear
D Posterolateral view of the reconstructed ear

skin graft, cut to pattern, is applied (Fig 1089B) The excess skin thus grafted assists in releasing tension in the area when the cartilage framework is introduced under the skin

A full thickness skin graft should be employed and an adequate time period should be allowed after transplantation of the skin A full thickness is preferable to a split thickness skin graft because the inclusion of the dermal plexus in the entire thickness of the dermis enhances the vascularization of the transplanted skin which must be raised as a flap in a later stage to permit the inclusion of the cartilaginous framework

Retroauricular skin from the opposite ear

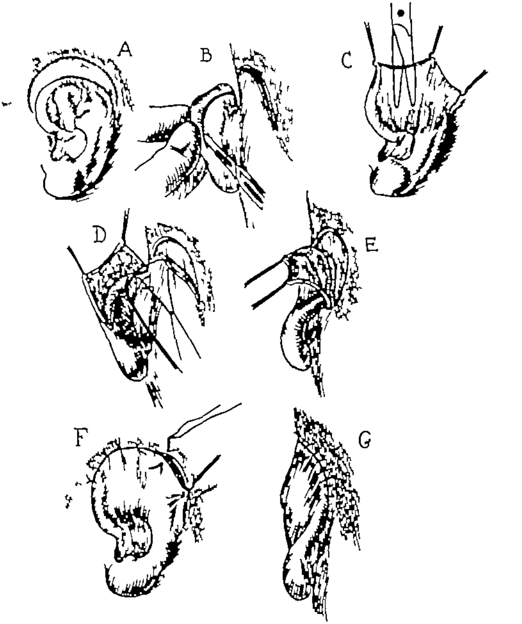

Fig 1087 The tunnel procedure for reconstruction following loss of the auricular framework
A. Outline of skin incision along the hairline.
B. Auricular incision made medially to the helix border
C. Separation of the cutaneous layers of the auricle.
D and E. Suture of the lower edge of the postauricular skin to the lower edge of the hairline incision.
F and G Suture of the upper edge of the auricular incision to the upper edge of the hairline incision.
(Figs. 1087 to 1092 from J M. Converse, Plast. & Reconstruct. Surg 22 150, 230, 1958)

under the skin of the area, and in a later stage replacing the hair-bearing skin by a skin graft. The second method consists of replacing the hair bearing portion of the scalp by a skin graft in a preliminary stage (Fig 1089*A B*) in a later stage, the cartilage implant is placed beneath the skin graft raised as a flap The second method is preferable to the first because it avoids the danger of denuding the implanted cartilage when the hair-bearing skin is excised. When this complication occurs the portion of the skin graft over the denuded cartilage fails to become revascularized and the exposed cartilage may become necrosed.

A crescentic area of scalp is removed and the excised area spreads to a larger size. A pattern is made of the enlarged defect and a

Fig 1088

A. Loss of the auricle as a result of traumatic avulsion by a human bite.
B. Result obtained by surgical reconstruction.
C. Close-up view of the reconstructed ear
D. Posterolateral view of the reconstructed ear

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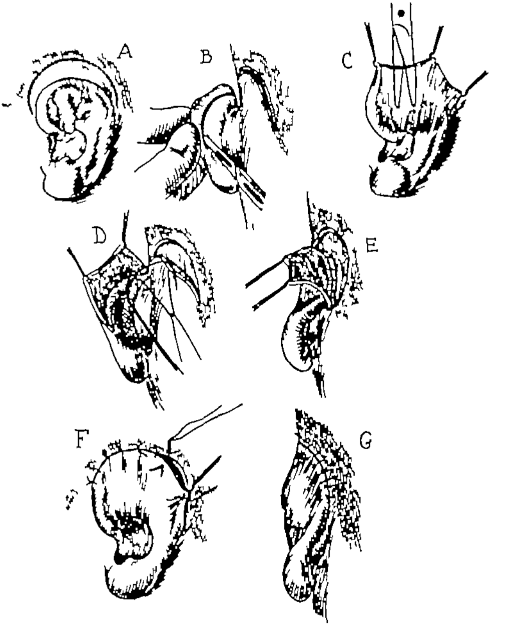
Retroauricular skin from the opposite ear



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(FIGS. 1087 to 1092 from J M. Converse, Plast. & Reconstruct. Surg 22 150, 230, 1958)

under the skin of the area, and in a later stage replacing the hair bearing skin by a skin graft. The second method consists of replacing the hair bearing portion of the scalp by a skin graft in a preliminary stage (Fig 1089*A B*) in a later stage the cartilage implant is placed beneath the skin graft raised as a flap The second method is preferable to the first because it avoids the danger of denuding the implanted cartilage when the hair bearing skin is excised. When this complication occurs the portion of the skin graft over the denuded cartilage fails to become revascularized and the exposed cartilage may become necrosed.

A crescentic area of scalp is removed and the excised area spreads to a larger size. A pattern is made of the enlarged defect and a

Fig 1088

Loss of the auricle as a result of traumatic avulsion by a human bite.

A. Loss of the auricle as a result of traumatic avulsion by a human bite.
B. Result obtained by surgical reconstruction.
C. Close-up view of the reconstructed ear
D Posterolateral view of the reconstructed ear

skin graft cut to pattern is applied (Fig 1089*B*) The excess skin thus grafted assists in releasing tension in the area when the cartilage framework is introduced under the skin.

A full thickness skin graft should be employed and an adequate time period should be allowed after transplantation of the skin

A full thickness is preferable to a split thickness skin graft because the inclusion of the dermal plexus in the entire thickness of the dermis enhances the vascularization of the transplanted skin which must be raised as a flap in a later stage to permit the inclusion of the cartilaginous framework

Retroauricular skin from the opposite ear

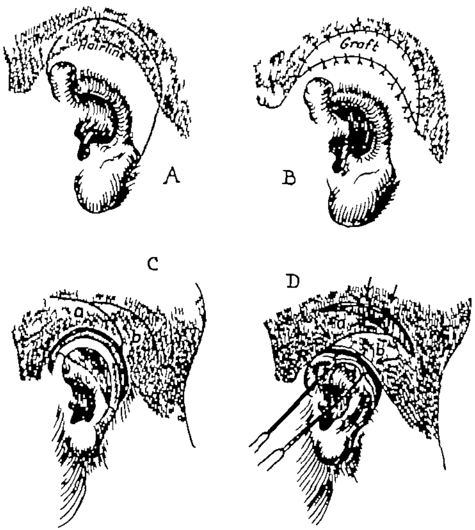

FIG 1089 Illustrating the management of the hairline

A. Position of the auricular remnants.

B Skin graft placed to provide hairless skin over the new auricle

C. After construction of the auricle the hairline is too high. Outline of imbricating flaps

D The hairline has been lowered by imbricating scalp flaps. Note also the adjustment of the lobe to the remainder of the auricle by Z-plasty procedure.

is the graft tissue of choice for two reasons (1) the skin is thin from a highly vascular structure and is rapidly revascularized (2) the color match is excellent. When retroauricular tissue is not available supraclavicular skin is the second choice

As the degree of protrusion of the reconstructed ear is usually less than normal it is undesirable to extend the hairline below the level of the upper border of the helix.

After the cartilage transplant is raised from the mastoid area and previous to skin grafting of the resultant raw area the scalp is advanced by the technique described by *Peer (1955) advancing and transposing two* imbricated scalp flaps (Figs 1089*C D* and 1090) Because the scalp is usually supple, particularly in children, the procedure permits the descent of the hairline to a suitable level We do not resort to scalp flaps which are rolled up temporarily and then rolled down at a later stage to restore an adequate hairline (White, Rubin and Walden 1956 Letterman and Harding, 1956)

THE AURICULAR FRAMEWORK. An adequate framework of cartilage is the key to satisfactory ear reconstruction. The elastic type auricular cartilage cannot be duplicated by cartilage from the costal cartilages. The au*ricular cartilage of the patient's avulsed ear*

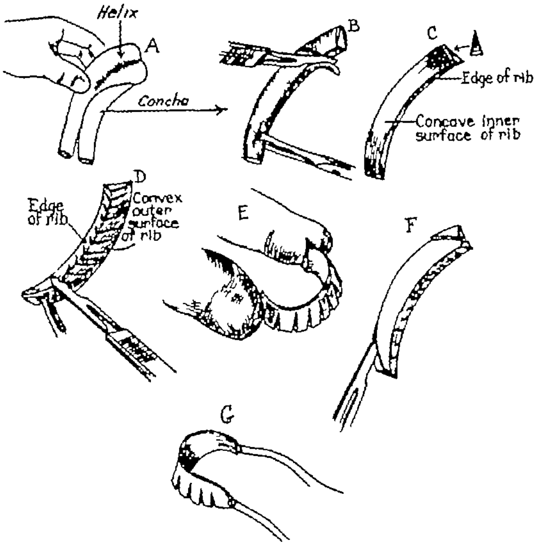

FIG 1090 Preparation of the antihelix implant

A. Cartilage graft consisting of two adjacent costal cartilages. The graft is divided into two sections. One section is utilized for the concha, and the other for remainder of the auricular framework.

B and C. The costal cartilage is trimmed, the cartilage assuming a triangular shape in cross-section.

D Oblique incisions extending through two-thirds of the thickness of the cartilage.

E. After incising, the cartilage may be bent into a suitable curve.

F The ends of the graft are bevelled.

G Final shape of the graft with the guide-sutures to assist in the introduction and fixation of the graft in the subcutaneous pocket.

may be utilized for reconstruction of the auricle as advocated by Greeley (1944) but this is a fortunate and rare occurrence for the surgeon (Sexton, 1955) Cartilage obtained by removing the concha from the unaffected auricle (Kazanjian 1949) may be employed to restore the missing helix

An adequate auricular framework awaits the solution of the homograft problem. One can anticipate perhaps in the not too distant future, the successful transplantation of auricular cartilage from a donor of close genetic relationship such as the patient's mother or father after the induction in the host of a state of acquired immunological tolerance The mere fact that an occasional cartilage homograft may survive is a demonstration of the feasibility of successful homotransplantation. The authors are aware of one patient in the series of maternal auricular cartilage transplantations performed by Gillies (1937) in whom the transplant continues to perform a supportive function twenty years after transplantation.

With the exception of conchal cartilage removed from the unaffected auricle, costal

cartilage is the only autogenous tissue available for a new auricular framework with the exception of meniscal cartilage (Mir y Mir 1952) with which the authors have had no experience

Costal cartilage is removed from the area of junction of the eighth ninth and tenth rib cartilages (Fig 1090A) The area is approached through a horizontally placed incision in one of the natural horizontal skin folds situated over the area to be exposed usually about two fingers breadth above the lower free margin of the tenth rib The fascia and muscle layers are sectioned and the perichondrium covering the costal cartilages is exposed In children two adjacent costal cartilages are required to obtain a block of cartilage of adequate size to permit carving the framework. Subperichondrial resection of two adjacent costal cartilages is not feasible because the perichondrium surrounding each rib with an individual sheath is invaginated between the costal cartilages Extraperichondrial resection increases the danger of perforating the pleura. The muscle layers must be dissected away from the perichondrium over the medial surface of the rib cartilage thus muscular layer is often thin, especially in children and care must be exerted to avoid perforating the pleura Costal cartilage graft resection should be done under a closed system of anesthesia to avoid collapse of the lung if a pleural tear occurs inadvertently

The natural curvature of the costal cartilage may be utilized to reproduce the characteristic auricular curvature (Byars and De Mere, 1950) the auricle inclined outward, the upper portion more distant from the side of the head than the ear lobe When costal cartilage is removed from the same side as the defective ear it can be turned inside out to reproduce the outward curvature and inclination of the auricle the perichondrium of the outer surface then becomes the inner surface and serves as a splint, binding the two adjacent costal cartilages together The perichondrium of the inner surface which is the outer surface of the new ear framework is removed in order to thin the cartilage and carve the depressions which form the characteristic convolutions of the framework

THE ANTIHELIX AND CONCHA Reconstruction of the ear is usually a more feasible procedure after traumatic loss of the ear

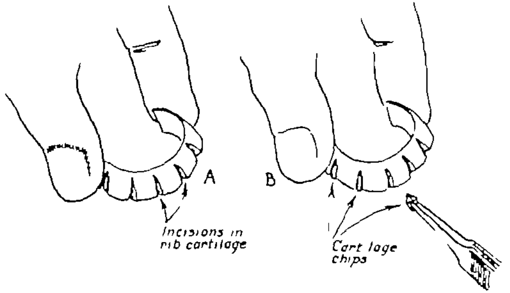

FIG 1091 Preparation of the antihelix implant

A. Incisions extending through two-thirds of the thickness of the costal cartilage permit bending the implant to a suitable curvature

B. The curvature may be maintained by wedge-shaped chips of cartilage placed in the gaping incisions.

than in the congenitally absent auricle. In traumatic defects a portion of the concha and the external auditory meatus are present these structures are missing in congenital microtia

Gillies suggested the possibility of employing bone as a means of obtaining a concha of adequate size and shape. This technique was employed (Converse 1950) but has been abandoned for the following reasons (1) the removal of an autogenous bone graft requires an additional operation and more extensive exposure in children because of the presence of the epiphyseal cartilage which forms most of the iliac crest in children five or six years of age (2) survival of the bone graft requires adequate subperiosteal contact between the transplant and the underlying bone of the mastoid regions such contact cannot always be obtained and absorption of the bone graft may occur (3) adherence of the bony concha to the underlying bone interferes with the subsequent raising of the auricle from the side of the skull.

A method which has proved satisfactory consists in removing the entire width of the costal cartilage, turning it on its side and slicing it repeatedly along its external border about three-quarters of the way through the thickness of the cartilage (Fig 1090*A B C D*) This procedure permits bending the cartilage to conform to the shape of the concha and antihelix (Fig 1090*E*, *F*, *G*)

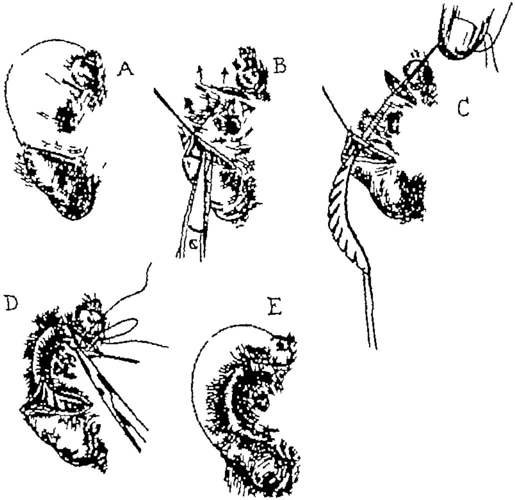

Fig 1092. Implantation of the antihelix graft

A. Skin incisions.
B. Undermining of the skin between the incisions.
C. Introduction of the cartilage implant under the skin by means of a traction suture.
D The costal cartilage implant is anchored to the vestigial cartilage by means of catgut sutures.
E. Appearance of the new concha.

Small chips of cartilage may be wedged into the incisions in the cartilage to assist in maintaining the curvature (Fig 1091) The transplant is placed subcutaneously and anchored anteriorly and posteriorly to the vestigiae with fine chromic catgut sutures (Fig. 1092) The concha is thus produced by the projection of the antihelix and by the external auditory meatus.

THE HELIX Conchal cartilage can be bor

A B C

Fig. 1093

A. Partial loss of the left ear due to burn.

B A conchal cartilage graft removed from the right ear has been placed beneath the postaural skin.

C. Result obtained after raising the cartilage transplant with the overlying skin and covering the raw area over the medial surface of the cartilage with a skin graft.

A B

Fig 1094

A. Partial loss of the right ear Note the tubed pedicled flap raised from the supraclavicular area.

B. Reconstruction achieved by using a conchal cartilage graft taken from the left ear and the tubed pedicled flap.

A B

FIG 1095

A. Partial loss of the right ear due to burns.

B. Result obtained by reconstruction with a conchal cartilage graft obtained from the left ear and a tubed pedicled flap raised from the neck below the collar line.

rowed without causing distortion of the donor ear An incision is made over the post auricular skin exposing the posterior surface of the conchal cartilage the cartilage is then incised just below the antihelix and the necessary amount of cartilage is removed (Figs 1093 1094 and 1095) The soft tissues and the periosteum over the mastoid region are removed in order to preserve the contour of the concha and the skin of the anterior surface of the concha is placed against the exposed bone and retained by a dental compound mold, pressed against the outer surface of the auricle.

When costal cartilage is employed the lateral surface of the transplant is carved to form the normal indentations and convolutions of the framework (Fig 1096*A B C D E*). The perichondrium covering the medial surface of the cartilaginous transplant remains undisturbed. The helix border is outlined with ink on the surface of the block or cartilage Gillies (1957) compared this outline to a question mark (Fig 1097) Excess cartilage is resected from the periphery of a first ink outline A second ink line is traced within and 3 or 4 mm. from the first outline. Cartilage is then gouged out of the area situated within the second ink line The cartilage along the rim of the graft thus projects in relief from the remainder of the cartilage and forms the protruding helix border of a normal ear cartilage Because the thin close-fitting cutaneous covering of the normal auricular cartilage cannot be duplicated the indentations of the lateral surface of the new auricular framework should be as deep and the portions in relief as sharp as possible. This is an essential precaution for the skin over the transplant tends to obliterate the sculptured cartilaginous landmarks. The portion of the auricle between the helix and the antihelix should be carved as deeply as possible with only a thin layer of cartilage remaining between the perichondrium on the medial surface of the implant and its lateral surface The projection of the helix margin is accentuated by the addition of a cartilage onlay maintained by fine stainless wire mattress sutures (Tanzer 1959) The

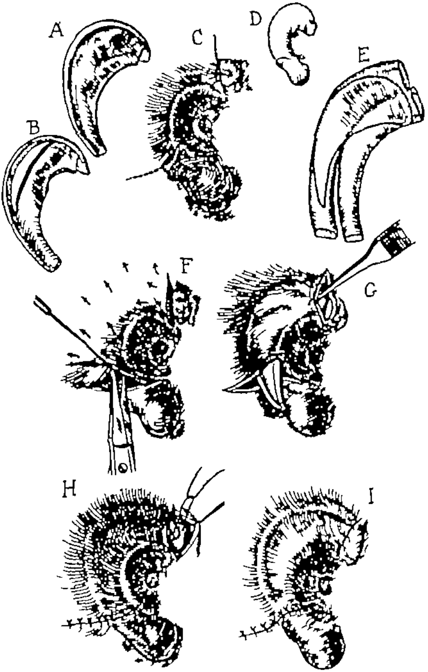

FIG 1096. Subtotal reconstruction of the auricle

A. Diagram of the carved cartilaginous costal transplant.
B. The graft may be fenestrated.
C. Outline of skin incisions for the introduction of the cartilage graft.
D Diagram of the position of the cartilage graft in relation with the auricular remnants.
E. Diagram representing the costal cartilages turned inside out. Outline of the area from which the auricular transplant is taken.
F Undermining of the skin between the two incisions.
G Introduction of the cartilage graft beneath the undermined skin.
H. Fixation of the cartilage graft to the vestigial cartilage.
I. Closure of the skin incisions.

(FIGS. 1096 to 1098 from J M Converse, Plast. & Reconstruct Surg 22 150 230 1958)

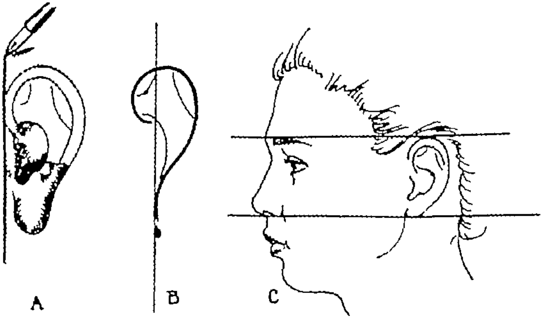

FIG 1097

A. An essential landmark in auricular reconstruction all of the structures of the auricle are situated posteriorly to a vertical line tangential to the lobe, the tragus and the anterior portion of the helix.

B. The outline of the auricle compared to a question mark.

C. Adequate length of the auricle determined by horizontal lines through the glabella and subnasale (the nasal spine)

auricular framework may be fenestrated (Steffensen, 1952) to insure the adhesion of the skin on the lateral surface of the implant to the skin graft on its medial surface (Fig 1096*B*) The coaptation of the two layers of skin serves to diminish the thickness of the auricle and also anchors the skin graft which lines the retroauricular fold, to the skin on the outer surface of the ear

Successful reconstruction of the auricle depends to a large extent upon the quality of the carving of the auricular framework and the presence of marked indentations simulating the convolutions of the normal ear the helix and the antihelix must be prominent, for these are the most characteristic portions of the ear

The incisions outlining the flap should leave wide attachments to the surrounding skin and prudence should be exerted when raising the skin flap previous to implantation of the cartilage graft (Fig 1096*F G H I*). If the skin flap is raised after a partly circumscribing semicircular incision a preliminary delay incision may be required to preserve the vitality of the flap if the auricular skin has been lacerated or burned. Undermining the skin is done at a superficial level to achieve close coaptation with the cartilaginous framework with only a thin layer of subcutaneous tissue being included. Survival of the cartilage implant depends upon survival of the overlying skin, for if the skin becomes necrotic through inadequate blood supply or an excessively compressive dressing, the cartilage is exposed is subjected to avascular necrosis and becomes softened, shriveled or eliminated Through-and through mattress sutures may be employed to apply the skin against the indentations of the cartilage framework. Prudence must be exercised in placing these sutures post-operative observation of inadequate vascularization is an indication for their removal

An important esthetic consideration is to place the auricular framework posterior to a vertical line drawn in front of the antitragus and lobe (Fig 1097)

Removal of the costal cartilage graft shaping and carving the transplant, and implanting it under a skin flap in the auricular

area are sequences which can be performed during a single operating session. If it is necessary to interrupt the operative procedure, the resected costal cartilage transplant can be preserved for later use in a subcutaneous pocket, formed by a plane of cleavage between the skin adjacent to the incision for exposure of the costal cartilage and the deep fascia It is usually advisable to implant the cartilage for the concha in a preliminary stage the conchal portion is removed from the main graft (Fig 1090*A*) and the remainder of the graft is buried under the skin of the chest.

RAISING THE EAR FRAMEWORK AND SKIN GRAFTING THE RETROAURICULAR FOLD. An incision extends around the periphery of the auricular framework and a cleavage plane is

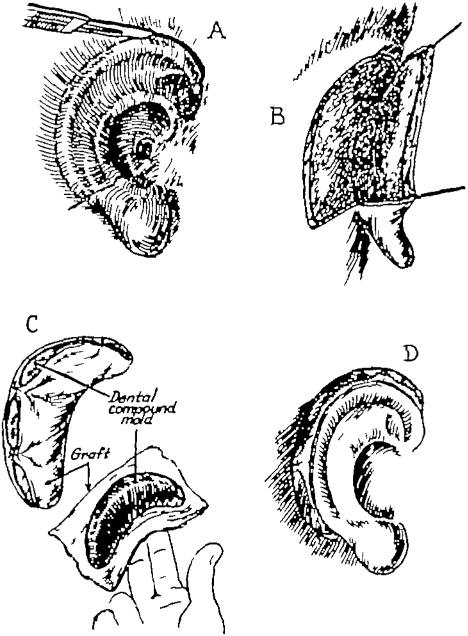

Fig 1098 Raising the auricular transplant and skin grafting the retroauricular groove

A. Incision made around the periphery of the cartilage transplant.
B. The auricular framework has been raised from the mastoid area
C. Dental compound mold with skin graft.
D Compound mold maintaining the skin graft in the retroauricular defect.

established medially to the structure, raising the auricle from the retroauricular area (Fig 1098) The resultant raw area is then covered by a split thickness skin graft from the inner aspect of the arm or the thigh for these areas are usually devoid of hair follicles.

The incision should be about 5 mm beyond the periphery of the cartilage to avoid exposing the rim of the helix (Fig 1098*A B*) The line of cleavage should also avoid exposing the cartilage, which remains covered by a thin layer of subcutaneous tissue this precaution is essential to provide the graft with a vascular host bed The groove is made as deep as possible for it has a tendency to become more shallow during postoperative healing

The area is covered by a skin graft after careful hemostasis. The epithelial outlay technique is preferred, employing dental compound, softened in hot water and pressed into the retroauricular raw area to form a mold. The mold hardened with a

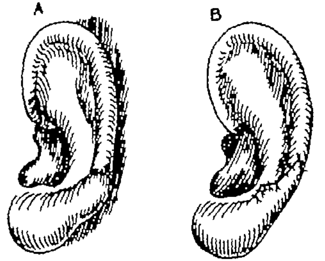

Fig 1099 Technique of removing the notch (A) between the lobe and the auricle, by the stepping, and by the tongue-and-groove techniques (B)

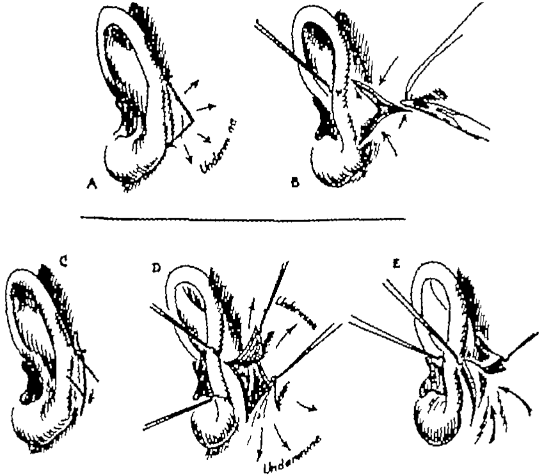

Fig 1100. Freeing the adhesion at the junction of the lobe and auricle.

A and B. The V Y advancement technique.

C, D and E. The Z-plasty technique.

(Figs. 1100 to 1108 from J M Converse, Plast. & Reconstruct. Surg. 22 150, 230 1958)

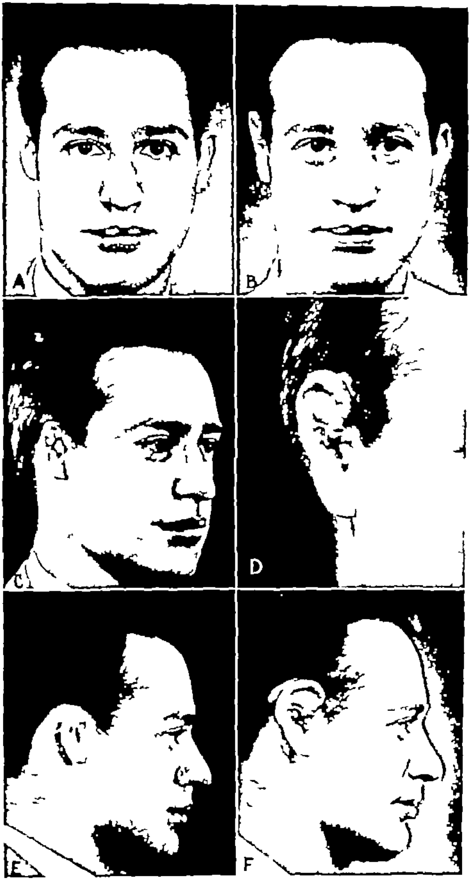

Fig 1101 Loss of the auricle

A, C, and E Showing loss of the helix.
B, D and F Restoration by techniques shown in Figures 1089 to 1090.

spray of cold water provides fixation of the split thickness skin graft which is wrapped around the mold raw surface outward (Fig 1098C D) A large fixed pressure dressing immobilizes the skin graft for a period of five to seven days. The entire area can be grafted successfully by following this technique carefully The mold should be large in size causing a protrusion of the auricle from the side of the head in order to increase the size of the retroauricular raw area In this manner the wider surface of the skin graft counteracts the tendency to subsequent contraction of the area and retraction of the auricle against the side of the head.

ADEQUATE PROTRUSION OF THE RECONSTRUCTED EAR. Suitable protrusion of the new auricle from the side of the head is one of the most difficult achievements in ear reconstruction. The curvature of the costal cartilage assists in obtaining an implant which protrudes from the side of the head in its upper portion as does a normal ear There is always a tendency that the new auricle be pulled against the side of the head by the progressive retraction of the skin graft placed in the retroauricular fold. This may be counteracted by having the patient wear an acrylic prosthesis for a number of months after the skin grafting: continued wearing of

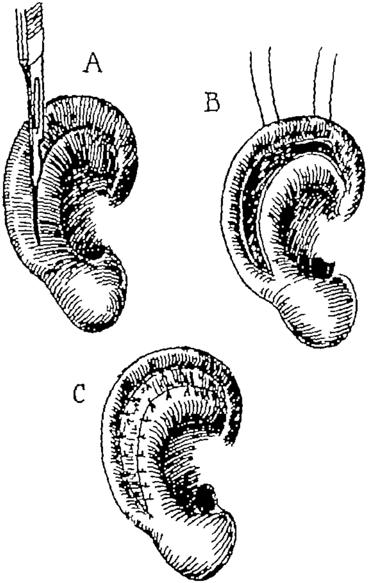

FIG 1102. Retouching procedure to increase the prominence of the helix border
A. Incision through the skin of the reconstructed auricle.
B. The peripheral skin is undermined and advanced toward the helix border
C. The resultant defect is covered by a skin graft.

prosthesis particularly in children is not ctical We have devised a small prosthetic ice for adult patients who wear spectacles ich is added to the posterior extremity of bow of the spectacles to insure mainte- ice of the satisfactory protrusion. Im ovement has been obtained also by addi ial secondary skin grafting to deepen the roauricular fold when performed a num of months after the original skin graft the release of tension by the additional n grafting permits the auricle to main n an adequate degree of protrusion from side of the head As adequate protrusion the reconstructed ear is usually not ob- ied the preferable procedure is to dimin the protrusion of the unaffected ear by operation of the type employed for pro- ding ears.

ADDITIONAL RETOUCHING OF THE RECON UCTED EAR. A remarkable degree of co- eration can be obtained with children o undergo multiple stage surgical proce es a large percentage will even accept al anesthesia for some of the secondary erations.

A notch which often forms between the e portion of the ear and the reconstructed ix, is usually corrected satisfactorily by a Z-plasty procedure The procedure consists of stepping the area of junction and in serting the angulated upper end of the lobe flap into the helix border by the tongue and groove technique (Fig 1099) Another com- plication is the tendency for the lower por tion of the auricle to adhere to the mastoid process at the area of junction with the ear lobe secondary skin grafting may be re- quired to elevate this portion. A V Y ad vancement of the skin in the retroauricular fold (Fig 1100*A B*) or a Z plasty procedure (Fig 1100*C D E*) may adequately correct this defect.

In some reconstructed auricles adequate contour is obtained by the carved cartilagi nous implant (Fig 1101) In others although the general shape and the degree of protru- sion of the new auricle may be satisfactory the indentations of the framework are not sufficiently accentuated, particularly in the area of the helix rim. Secondary corrective procedures can be divided into four groups

1 The first method consists of removing additional cartilage to increase the concav ity of the auricle and the relative projection of the helix border The incision through the skin to expose the area is made where the indentation of the cartilage begins the

Fig hing procedure to incre nence of the helix border

A. Dotted are ent of cartilage to i

B. Illustrates re e of cartilage throu edial aspect of the auricle.

C. Technique o to increase the pro helix border

chances of maintaining the indentation are better because contraction during healing applies the skin against the deepened cartilaginous groove.

2. In a second method the skin covering the auricular framework is undermined, advanced and plicated to increase the helix border prominence (Fig 1102*A* *B*) A skin graft covers the resultant raw area (Fig 1102*C*)

3 A third method for increasing the prominence of the rim of the helix is a variation of a technique described by Cronin (1952) An incision is made through the skin 1 to 2 mm from the outer rim border of the auricle (Fig 1103*A*) The excision of a crescentic shaped piece of cartilage decreases the height of the auricle and increases the relative amount of skin available for tubing (Fig 1103*B* *C*)

4 The fourth method consists of adding a fine-calibered tubed pedicled flap to the rim of the auricle Cervical tubed flaps have been employed these have been found to be

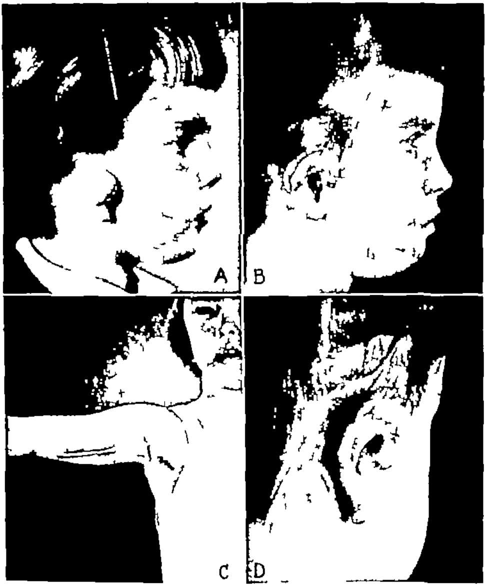

Fig 1104

A. Congenital microtia with congenital facial paralysis. Note anteroinferior position of the auricular remnants.

B. After splitting the remnants, the defective auricle was restored by a costal cartilage implant. A brachial tubed pedicled flap was added to the helix rim.

C. Small calibered tube constructed on the inner aspect of the arm.

D. Posterolateral view of the constructed auricle.

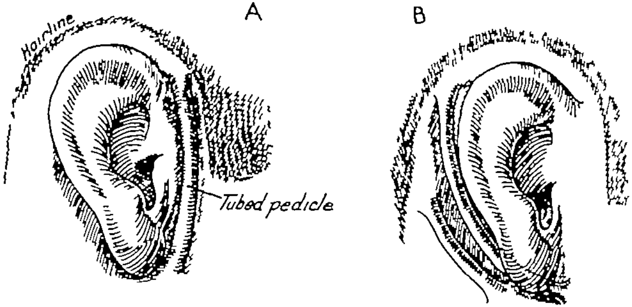

FIG 1105 Preauricular (A) and postauricular (B) tubed pedicled flaps.

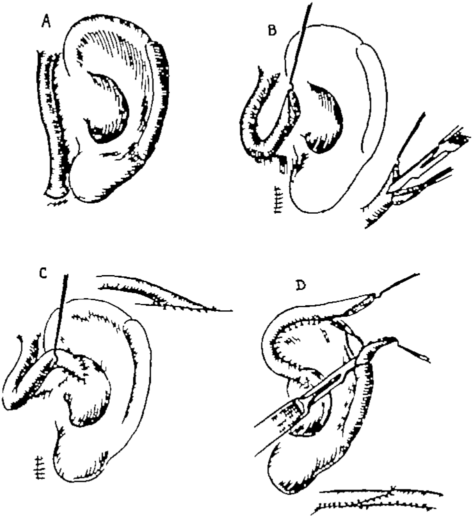

FIG 1106. Stages in the transfer of a preauricular tube to the auricle

A. The dotted line indicates the level of section of the lower attachment of the tube

B. The lower end of the tube is bevelled prior to implantation in the concha.

C. Showing attachment along a bevelled plane (see insert) in the concha.

D Attachment of the remainder of the tube to the helix margin The end of the tube is sutured to a previously implantd retroauricular tube by a bevelled line of junction this technique prevents notching

FIG 1107 Reconstructed auricle with a postauricular tubed flap attached to the helix rim and a preauricular tube to provide the anterior portion of the helix rim, thus completing the anterior curvature of the question mark (see Fig 1106)

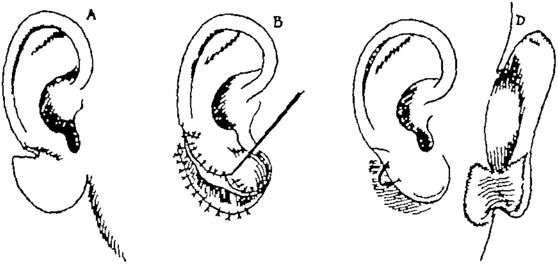

FIG 1108. Reconstruction of the ear lobe

A. Design of the flap.

B. The posterosuperior angle of the flap has been inserted into the lower portion of the hel raw surface of the flap and of the donor area of the flap is covered by a full thickness graft.

C. As healing takes place the edge of the flap tends to roll on itself.

D Postoperative appearance of the new lobe (see also Fig 1088)

unsatisfactory occasionally because they cannot be made of sufficiently fine caliber Horizontal cervical flaps are preferable to vertical flaps, which usually result in hypertrophic scarring but also have the inconvenience of requiring multiple stages for their transfer Fine calibered tubed flaps (Fig 1104) may be obtained from the inner aspect of the arm (McNichol 1950) Some disparity in color with the surrounding skin is noted after the transfer of these brachial tubed flaps. Their greatest inconvenience however is the need for immobilizing the upper extremity in close proximity to the head during the position of transfer Young children appear to withstand the discomfort of such a position always a disturbing experience for the adult patient A preferable technique is the employment of tubed pedicled flaps from the immediate vicinity of the defect from the retroauricular (Steffanoff 1948) and preauricular areas (Fig 1105) There is always sufficient skin devoid of hair follicles between the auricle and the bearded area of the male patient to permit construction of a tubed flap in the preauricular area. These tubed flaps should be about 1.25 cm. in width The flap is raised by transecting the fat layer from the base of the dermis this precaution is necessary to permit tubing a flap of such narrow dimensions. The thickness of the flap is that of a full thickness graft from which the remaining fat has not been trimmed with scissors. It is necessary that these tubes present a fine caliber for the caliber usually increases slightly after they are transferred and secondary attempts to thin a tubed flap after it has been placed along the rim of the auricle are not always successful

A preauricular and a postauricular tube are usually required they are united by an oblique line of junction in order to avoid notching (Fig 1106) These tube flaps should be inverted into an incision along the free margin of the auricular framework Fig 1107 illustrates a reconstructed auricle which requires the addition of a fine-calibered tube to complete the helix border contour

Reconstruction of the Ear Lobe

Construction of an ear lobe is not usuall required in congenital microtia the lob being formed from the misplaced auricula remnants. A portion or the entire lobe ma be missing in traumatic loss of the ear

The operation of Gavello (Nélaton an Ombrédanne 1907) consists of preparing bilobed flap the posterior lobe being folde under the anterior one thus serving as th inner lining of the new ear lobule.

Reconstruction of the ear lobe may also b achieved by a simpler technique. An in line outlines the shape of the new ear lobe allowing an increase in size of approximatel one-third The flap is raised from its be with the base of the flap above (Fig 1108*A*) A full thickness graft of retroauricular o supraclavicular skin covers the entire defec produced by raising the flap (Fig 1108*B*) At the uppermost portion of the defect where the flap is attached at the base of it pedicle the skin graft is reflected downward, covering about two-thirds of the raw undersurface of the flap (Fig 1108*C D*) A the flap heals the tendency for the edges o the flap to curve toward the skin grafted sur face is accentuated thus simulating th shape of a lobe (see Fig 1088)

Complications

It is generally agreed that total reconstruc tion of the ear remains a difficult and ofter discouraging surgical problem Ferris Smith (1950) has drawn attention to the fact tha the external ear is thinner than the two ap proximated layers of average thickness skin. A layer of costal cartilage must also be in cluded its thickness must be sufficient to permit carving and shaping and still retain its form and supportive strength In addi tion the auricle is separated from the side of the head remaining attached only in its anterior portion To construct a structurally thin well-shaped auricle which protrudes

om the side of the head with an adequate troauricular fold the surgeon balances on tight-rope between beauty and blood sup y

The most frequent serious complication exposure of the transplanted cartilaginous amework due to necrosis or unsatisfactory aling of the covering skin flap or graft posure of the cartilage occurs mainly ong the margin of the helix and is always a serious complication because of the danger of avascular necrosis and secondary infec tion Attempts at approximation of the soft tissue wound edges by suture rarely succeed because of tension Imbedding the exposed area into an incision in the scalp or covering the cartilage with a flap of adjacent scalp are procedures which should not be delayed. Later excision of the hair bearing tissue and replacement by a skin graft are required

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BURNS OF THE FACE

INTRODUCTION

Burns of the face are caused by a great variety of agents. A majority of burns are incurred in the home Infants have been burned by accidentally falling into an open fireplace Children have been burned by placing a live electric socket in the mouth or while playing near a kettle of boiling water or a steam radiator Fourth of July burns from explosive powder are a common occurrence. Severe burns are incurred by epileptics who fall into an open fireplace or against a hot stove or steam radiator while unconscious.

Burns of the face often result from explosions of gasoline in automobile and air plane accidents these are usually deep burns of the hands and face, similar to those observed in Air Force and tank personnel during the late World War

Many burns are traced to industrial accidents for example acid burns, chemical burns and burns from molten metals Burns have also been incurred in the business office a celluloid eye shield ignited by a cigarette has caused severe burns of the face In one case a fluorescent light bulb falling on the face resulted in a granulomatous burn wound which failed to heal similar in appearance *to a malignant lesion*

Major catastrophes, such as train accidents fires in theaters, hotels, or other public places have resulted in burn accidents to large numbers of people Severe facial disfigurements have resulted from the deliberate throwing of acid Radiation burns, as a result of treatment by x ray or radium and burns from the industrial use of atomic energy are additional types of burns.

The problems attending the treatment of burns of the face cannot be dissociated from those of burns in general for the facial burn may be only a part of an extensive burn which involves other areas of the body Burns of the face and neck are frequently associated with burns of the hands in gasoline and flash burns the remainder of the body protected by clothing, may not be involved.

According to Berkow's chart, a burn of the entire face represents 3 per cent of the body surface the entire head represents 6 per cent The face comprises a relatively large proportion of the total skin area in infants In adults, a burn of the face alone does not necessarily endanger life although the loss of plasma from the circulating blood volume is relatively large in comparison with the limited surface burned the loosely attached tissues of the face and neck permit the collection of a large quantity of fluid

THE MANAGEMENT OF SHOCK AND METABOLIC ASPECTS OF BURNS

Local tissue changes have a systemic repercussion in the early stages of burns. The patient shows signs of primary shock immediately following the injury Treatment consists of sedation supportive fluid therapy and measures to warm the patient

...uted by Ernest S Breed, M.D Depart... New York University College of

Secondary shock following extensive burns may cause death during the first forty eight hours.

Heat causes damage to cells resulting in altered permeability or actual death due to coagulation The blister or bleb formation characteristic of second degree burns is an example of the change in cellular permeabil ity Blister fluid contains 3 to 4 grams per cent of protein and the ions sodium chloride and potassium, as well as water in approxi mately the same proportions as in plasma The results obtained from experimental studies of severe burns of an extremity in the dog (Cope and Moore, 1947) have shown that the venous blood returning from a burned limb contains a higher concentra tion of potassium than the arterial blood to the injured limb (Henry and Amspacher 1954) Fox and Baer (1947) have reported that burned tissue absorbs sodium and water and releases potassium.

Third degree burns are characterized by coagulation of tissue without bleb forma tion with a wide area of edema adjacent to the burn. An intravascular lysis of red cells with resulting hemoglobinemia and hemo-globinuria often occurs in this type of in jury (Moore Peacock, Blakely and Cope 1946) which may result in the syndrome of acute renal failure in inadequately treated patients. Other more recent studies in dogs employing radioactive chromium to measure the red cell mass have tended to show a lesser degree of red cell destruction in burns, com parable in extent to those commonly seen in human subjects About an 8 to 10 per cent destruction of the original red cell mass has been estimated for the average burn Pro-longation of the time of contact between tis-sue and heat source, however has resulted in increased destruction of red cells to about 40 per cent of the original red cell volume (Raker and Rovit, 1954) the amount con sidered "trapped" in human burns as meas-ured by the T1824 blue dye technique for plasma volume. The volume loss of red cells has been the rationale for the use of whole blood in the therapy of severe burns (Evans and Bigger 1945)

TABLE 7

Head 9 per cent	Entire upper extremity 9 per cent × 2 = 18 per cent
Trunk anterior surface, 18 per cent	Entire lower extremity 18 per cent × 2 = 36 per cent
Trunk posterior surface, 18 per cent	
Perineum 1 per cent	
Neck 1 per cent	

In general the greater the surface area of the burn the greater the fluid loss Estimates of the surface area involved can be made on the basis of Berkow s tables (1924) or by means of the rule of nine (Table 7) of Wallace (1951)

As a result of studies delineating the var ious processes described, Cope and Moore (1947) and Evans (1952) devised formulae to serve as guides for fluid therapy in burns, and to mirror the rate and kind of fluid loss Evans formulae follow

1 One cubic centimeter of volume mul tiplied by the body weight of the patient in kilograms multiplied by the per cent of body surface area equals the number of cubic centimeters of colloid (blood plasma or plasma expander) (Cordice, Suess and Scudder 1953) required to replace the rapid loss of fluid during the first 24 hours after injury

2. An equal volume of saline or prefer ably a mixture of one third sodium bicar bonate or sodium lactate and one third so-dium chloride is also required.

3 Two thousand cc. of 5 per cent glucose in water are given for insensible loss and urine requirements (Moore Peacock Blakely and Cope 1946)

One half of the calculated amounts of col loid and sodium chloride are given during the second 24 hours, when tissue tension is building up and the rate of fluid is slower (Table 8).

TABLE 8

1 cc. × 70 kg × 40 per cent surface area burn	2800 cc. colloid 2800 cc. saline
First 24 hours	2000 cc. 5 per cent glucose in water
Second 24 hours	1400 cc. colloid 1400 cc. saline 2000 cc. 5 per cent glucose in water

The red cell loss in third degree burns seems to be adequately replaced when half of the required colloid is given as blood and half as plasma or plasma expander. Catheterization of the bladder is recommended to follow and maintain the hourly urine flow between 25 and 50 cc. per hour by adjusting the rate of infusion. Fluids given too slowly or in insufficient total amounts permit the occurrence of shock, with its associated renal ischemia (Lauson, Bradley and Cournand 1944); this together with hemoglobinemia may set the stage for acute renal failure (Cope and Moore 1947). The liberation of potassium from the burned area may then result in a rapid increase in concentration of this ion to toxic levels in the plasma (above 7 mEq. per liter), since the usual urinary loss of the potassuim ion is prevented by the onset of anuria. Intensive resin therapy by the rectal route is required (Elkington, Clark, Squires, Blueme and Crosley 1950) together with intravenous glucose, insulin and some saline. If the urine flow fails to return promptly, dialysis by means of the artificial kidney is mandatory since the conservative management of anuria has little to offer in the face of the catabolic changes which are so characteristic of severe burns.

Adequate fluid therapy of severe burns is not associated with renal damage (Haynes, de Bakey and Denman 1951). The establishment of high urine flows over 50 cc. an hour, however, indicates excessive fluid therapy, and in the presence of pulmonary burns, may precipitate pulmonary edema [illegible] 1947 [illegible] sterne ability is restored after 48 hours and the "third space" or "porositic extracellular" space surrounding the burn begins to be reabsorbed. If this edema fluid has been increased to a degree equal to the subject's own extracellular space (approximately 20 per cent of body weight, 14 liters for a 70 kg. man) by excessive fluid administration, the patient may be unable to excrete the fluid as rapidly as it is being mobilized. The resulting increase in plasma volume in some elderly subjects may result in pulmonary edema on the third to the fifth day after injury (Cope and Moore 1947).

For this reason, Evans has warned that no patient should receive more than 4000 cc. of colloid and 4000 cc. of saline in the first 24 hours, and that burns above 50 per cent should be treated as though they were only 50 per cent in extent to avoid the lethal results of the administration of too much fluid (Evans, Purnell, Robinett, Batchelor and Martin 1952). As a result of this spontaneous mobilization of fluid, no colloid or saline infusions are administered on the third and fourth days after injury. Most of the edema fluid is usually gone by the fifth to the seventh day. As a result of large urinary losses and poor intake during the first few days, potassium deficiency may develop unless potassium containing fluids, or a regular diet are given from the fourth day on (Blocker, Levin, Nowinski, Lewis, and Blocker 1955).

Concomitant with the inception of the burn, a powerful adrenocortical stimulation is produced, which is manifested by a drop to zero in the eosinophile count of the peripheral blood. At the same time there is a marked increase in the output of corticoids and 17-ketosteroids in the urine (Wilson, Lovelace and Hardy 1955).

The eosinophile count rises above 50 per cubic centimeter about the third day after the burn in patients with a good prognosis (Wight, Raker, Merrington and Cope 1953). The [illegible]rsistence of a depressed eosinophile c[illegible]ally associated with a poor prog[illegible]n Lovelace and Hardy 1955).

This response appears to be maximum re gardless of the size of the burn except in very small burns. Elevated eosinophile counts in severe burns have not been observed (Wight, Raker Merrington and Cope 1953 Wilson Lovelace and Hardy 1955)

The hyperglycemia associated with the adrenocortical response together with forced feedings of a high caloric high car bohydrate nature, complicate the early days of the post-shock period by giving rise to a state of pseudo-diabetes marked by dehy dration uremia cerebral depression and death (Evans and Butterfield, 1951)

How much hyperalimenation is compat ible with the well being of the patient dur ing the first two weeks after the burn? Marked loss of weight was observed in se verely burned subjects by Blocker Levin Nowinski, Lewis and Blocker (1955) when the daily intake fell below 2 to 4 grams of protein and 35 calories per kilogram body weight per day Admission weight could only be maintained by 2 to 4 grams of protein and from 45 to 85 calories per kilogram Only ambulatory patients treated by the ex posure method, were capable of tolerating this large intake.

The basal metabolic rate of extensively burned patients has been found to be ele vated 50 per cent to 60 per cent for as long as two months after injury This elevation has been found to be unrelated to tempera ture or to thyroid gland activity as measured by the protein bound iodine of the blood as by radioactive iodine uptake (Cope, Nardi Quijano, Rovit, Stanbury and Wight 1953) This may account for the marked tendency to lose weight, in addition to actual surface losses.

When plasma is used as one of the replacement substances the risk of serum hepatitis is always present and may well be a lethal factor when anorexia and signs of liver damage appear in the severely pa tient.

Infection of the burned are

by an elevation of the temperature may sig nal the onset of septic toxemia, a complica tion accompanied by severe anemia Patients who survive the period of shock may die as a result of infection of the burned areas. The prevention of sepsis in the burn wound is essential following the early management of shock The use of antibiotics is included in the protective measures. The modern treatment of burns has done much to dimin ish the danger to life resulting from infec tion

THE HEALING OF BURNS

Burn wounds are divided into two groups superficial burns in which partial destruc tion of the skin has occurred and deep burns characterized by destruction of the full thick ness of the skin The differing terminologies in the classification of burns have caused confusion Six degrees are distinguished in Dupuytren s classification three degrees are listed in another Figure 1109 lists the ter minology used in this text (Converse and Robb-Smith 1944)

The healing of superficial burns follows the healing pattern of superficial or dermal wounds described in Chapter 2. Intersland contraction between the healing epidermal elements in the dermis accounts for the resulting contraction tightness and apparent loss of skin which occurs following healing The contraction may cause ectropion of the eyelids, retraction of the alae of the nose and stiffness of the lips and cheeks Changes occur in the color and quality of the skin The healed area is generally pink in color occasionally it is paler than the unaffected neighboring skin deep pigmentation sometimes occurs. In mixed burns the skin of the healed area is coarser than usual with wide pores and occasional scars. Deep or full thickness skin burns heal *similarly to* wounds with loss of skin (see Chapter 2)

Epidermal Burns

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FIG 1109 Classification of burns

Dupuytren	American		Converse and Robb-Smith	
Degree	Degree	Depth of Burn	Description	Prognosis
1st	1st	Epidermal	Erythema followed by desquamation	Heals well
2nd	2nd	Dermal	Blistering and superficial destruction of the dermis	Heals well
3rd	2nd	Deep dermal	Destruction to deep layers of dermis	Heals slowly
Mixed 3rd and 4th	Mixed 2nd and 3rd	Mixed burns	Small areas of deep dermal alternate with small areas of deep burns	Heals slowly
4th, 5th and 6th	3rd	Deep or full thickness	Destruction of whole thickness of the skin into or beyond the fat	Heals with difficulty Produces contractures unless grafted

mation a temporary pigmentary change remains in the skin A detailed study of the early histological changes in experimental burns in animals was reported by Leach Peters and Rossiter (1943) comparable changes have been observed in man

Dermal Burns

Blistering is the rule in dermal burns Blisters are caused by an epidermo-dermal separation produced by the exudation of fluid. Less frequently the layer of separation is sometimes deeper than the junction of epidermis and dermis, and occurs within the dermis

Healing may be anticipated in seven to ten days if the base of the blister is red smooth and moist and is not infected Epithelization originates from the few remaining islands of basal epithelium and from the hair follicles and sweat ducts (see Figs. 33 to 46 Chapter 2) The healed burned area remains pink for a few days or weeks and usually regains a normal appearance later

Deep Dermal Burns

A thicker layer of dermis destroyed in deep dermal burns results in a superficial slough which separates leaving the remaining dermis with a grossly punctate appearance Numerous small islands of epithelium resembling minute pinch grafts, are observed in the course of healing A pearly white thin layer of epidermis spreads from these islands. Healing is prolonged particularly in infected cases the healed area is scarred shiny and dry The burned area contracts considerably during the process of healing

Mixed Burns

The appearance of mixed burns is similar to that of deep dermal burns, except that small granulating areas appear following the separation of sloughs. Healing occurs slowly with a great deal of contraction and the repair is often unsatisfactory The scarred tight skin is subject to ulceration and interferes with movements of the muscles of expression

Deep or Full Thickness Burns

It is often difficult to determine the exact depth of the burn at the initial stage Charred tissues indicate an obvious full thickness skin loss. A superficial burn of the dermis can be anticipated when the burned area is red and sensitive to touch Blanching on pressure indicates that the subpapillary plexus and capillary loops contain flowing blood The deeper tissues are probably involved when the burned area appears white or gray leathery dry and

relatively non-painful to touch. The degree of damage is usually determined after the formation of a devitalized tissue slough which appears white then yellow and later turns black. The slough begins to delimit itself about the fifth day a well-defined demarcation line is formed between the fifth and tenth day This "skin sequestrum contracts, leaving a groove between itself and the surrounding tissue. The slough separates by liquefaction of the cleavage plane between living and dead tissues as a result of bacterial invasion of the intermediary zone The process of spontaneous separation and elimination of the slough occurs after a number of weeks, exposing a wound of unhealthy appearance which granulates rapidly The granulating area heals by epithelization from the surrounding skin and in the hair bearing skin of male patients, from deeply embedded hair follicles The process may extend over a period of many weeks during this interval changes in the granulating wound often lead to deforming contractures and distortion (see Chapter 2)

Fibroblasts at the base of the granulations tend to arrange themselves horizontally after four to five weeks, forming gross collagen fibers which increase in the wound obliterating many of the blood vessels. Superficial necrosis may occur owing to the decrease in blood supply secondary infection is invited. Contraction and resulting deformity are severe in the vicinity of the eyes, cheeks, lips and neck where the tissue is loosely attached Most burns show varying degrees of burning in different areas. Thus certain areas may be full thickness burns while adjacent areas are superficially burned.

DIAGNOSIS OF THE DEPTH OF A BURN

Dupuytren (1832) noted contracture-deformities following burns 'We must here note a phenomenon which is peculiar to burns and which no other wound with loss of substance presents in the same degree this is the power with which the edges of the wound are drawn toward the center We cannot agree with Dupuytren that the burn wound shows a special propensity to contract The loss of skin is often greater in burns than in other types of injuries, thus accounting for the severity of the contractures. Early diagnosis of the depth of a burn of the face is important for skin destroyed in a deep burn requires early replacement skin grafting performed early minimizes the subsequent contracture and deformity The skin graft should be placed not later than three weeks after injury or just as soon as the limits of the full thickness loss can be determined this can be decided on the day of injury in some cases and during subsequent weeks in others. The diagnosis of full thickness skin loss is often difficult immediately after burning and in the past has usually depended upon the clinical judgement of the surgeon rather than accurate description and definition

The probable depth of the lesion can often be gauged by an awareness of the causative agent. Burns caused by molten metal and red hot metal are most always full thickness skin loss electric contact burns are frequently associated with even deeper necrosis Full thickness flame burns in epileptics are more readily diagnosed having the appearance of translucent parchment through which the thrombosed cutaneous veins can be seen

Testing for analgesia is a method for evaluating full thickness skin loss in burns Before proceeding with this measure first noted by Dupuytren (1832) the patient should be made aware that the necessary probing may be painful The lesion is touched lightly with a sterile hypodermic needle in the area where the burn appears to have been of greatest intensity to test for sensitivity firm pressure upon the skin is required however before the presence of analgesia is recorded. As pointed out by Jackson (1953) it is necessary to test an area of 2 to 3 cm., for the pain spots are localized

and the areas of full thickness skin loss may be patchy The age and nervousness of the patient must be considered as with all subjective tests. Full thickness burns are analgesic pain upon testing indicates a partial skin loss.

Analgesia is the most reliable early sign that the burn is deep but does not imply that the burn is necessarily full thickness. The diagnosis of the depth of the burn must be considered together with the history and the site of the injury

Apart from the obvious full thickness skin loss seen in epileptics, analgesic burns of the face and scalp should not be excised primarily The hair follicles penetrate beyond the dermis, and deep burns often recover with minimum scarring after a period of 2 or 3 weeks. If the burn is of partial thickness skin early excision and skin grafting may result in an undesirable skin covering of poor texture and color

If after these considerations doubt still remains as to the depth of an analgesic burn the management should be planned with special reference to the expected healing time and the texture of the skin which will result an important consideration in burns of the face.

In localized burns, such as burns by acid or molten metal free thickness skin destruction appears probable and early excision and grafting desirable

Some surgeons choose between the fifth and tenth days for excising and skin grafting using the superficial white necrotic slough as a guide to the amount of full thickness skin loss. Unfortunately there is no criterion for diagnosing full thickness skin destruction even at this period although burn wounds can be excised more reliably and grafted more sucessfully at this time than on the day of injury

It is almost always possible to diagnose the limits of skin destruction by the tenth to the fifteenth day After this period further postponement to prepare the granulation tissue for grafting serves no useful purpose and subjects the burned patient to additional delay during which the risk of infection is increased If the granulation tissue is not sufficiently healthy for a skin graft, it should be removed by scraping it away with the edge of a scalpel blade before grafting

Treatment of the Burn Wound

Local treatment of the burn wound is initiated after systematic supportive therapy has been instituted.

The objectives in the early management of a facial burn are the prevention of deformity and the preservation of function. To attain these objectives requires.

1 Avoiding further destruction of remaining viable epithelium by mechanical injury and bacterial proliferation

2 Securing rapid healing of areas of superficial burns and rapid separation of the burn slough and a suitable surface for early skin grafting in deep burns.

The methods employed in early treatment should be practical under varying conditions a pressure dressing over the face for example feasible under normal conditions, proved uncomfortable in the intense heat of North Africa.

Local care of the burned face can be initiated following sedative medication relieving pain by intravenous doses of 6 to 10 mg of morphine, and systemic supportive therapy

Vigorous cleansing as formerly advocated should be avoided it is ineffective in reducing the number of contaminating organisms injures the remaining epithelium in the burned area and requires general anesthesia

Gentle cleansing does not injure the remaining epithelium it is accomplished without rupturing the blebs and without a general anesthetic and permits inspection and an initial gross estimation of the depth of the burn (Fig 1110*A B*) The absence of initial cleansing of the burned area however does not appear to affect the subse

Fig 1110 Appearance of deep burn of the face

A. Appearance of Air Force officer two hours after burn sustained in crash of bomber

B. Appearance after gentle cleansing of the face with detergent Edema of the facial tissues is marked The eyelids are shut, the lips puffed out.

C. Appearance of the patient the next day Note extensive edema of the base of the neck.

D Appearance three weeks later after sloughs of deep burns have been removed. The patient is ready for skin grafting The earlier skin grafting is practiced in these cases the less will be the contraction of the tissues and resulting contracture.

quent course of the burn or its healing process (Cope, 1943)

Gentle cleansing with gauze pads and a bland soap is adequate to remove detached epidermis smoke debris or grease Heavy grease or oil is dissolved by a trichlorethylene spray or benzene

Removal of the outer layer of the bleb is a usual practice to rid the wound of a culture medium for the growth of organisms, thus serving the same purpose as early debridement or removal of devitalized tissue in deep wounds. It is generally believed that the fluid of the unpunctured blebs may become purulent the fluid providing an anaerobic culture medium It is probable however that the blister fluid has a relatively high oxygen content (Field, Drinker and White 1932) unsuited for the growth of the anaerobic organisms, and that infection of unruptured blebs, produced by the normal bacterial inhabitants of the skin or an occasional virulent organism can be controlled by antibiotics (Lyons, 1943) Healing has occurred with equal rapidity beneath either the ruptured or unruptured bleb (Cope, 1943) Because of the fact that most blisters rupture spontaneously before healing is complete it is preferable to rupture the blisters initially and cut away the covering epithelium with scissors.

Open Treatment versus Pressure Dressings

Theoretically pressure dressings avoid bacterial contamination and promote healing by immobilizing and protecting the tissues minimizing edema and favoring venous return

Practically the open treatment advocated by Wallace (1919) is the preferable method in the early stages of treatment of burns of the face. Pressure dressings are used only to prepare the granulating areas of deep burns for skin grafting The "weeping areas become dessicated and covered by a crust formed of dried exudate which appears to protect the healing burn wound for it remains free of signs of infection Formation of the crust is hastened by employing an electric hair-dryer to blow dry warm air upon the face The crust once formed provides the burn wound with a physiologic dressing which appears to be a more effective deterrent to bacterial growth than locally applied ointments containing antibiotics.

Care of the Eyes

The eyes should be irrigated with saline solution to remove foreign bodies which may have entered the conjunctival sac at the time of injury The patient should be questioned frequently regarding ocular discomfort if pain or a grit like sensation is reported the eyes should be examined. Frequent irrigation of the conjunctival sacs with saline solution and the use of an antibiotic ointment are necessary precautions against infection These precautions also prevent the eyelid margins from becoming adherent and serve to reassure the patient that the vision is not affected When the lids are not in apposition moisture of the cornea should be maintained in order to prevent ulceration Moist pads should be placed over the eyes especially at night in sedated patients.

Ectropion of the eyelids a common result of burns, is caused by either scar contracture in the eyelids or in the areas surrounding the eyelids (see Chapter 21) Various measures have been advised to prevent early ectropion Partial or complete tarsorrhaphy undoubtedly affords protection but unless skin grafting is performed early the tarsorrhaphy may also be pulled apart as the contracture of the wound increases. Early skin grafting is the only effective means of protecting the ocular globe and should always be given priority over any other skin grafting procedure in the burned patient The technique of skin grafting of the eyelids should provide for the placing of an excess of skin graft in order to allow for subsequent contraction (see Chapter 21).

Edema

The edema which accompanies a burn of the face often reaches tremendous proportions the eyelids are puffed out and tightly shut by the swelling the lips and the cheeks present a balloon like appearance (Fig 1110C) The edema spreads into the neck and chest within the first twenty four to forty-eight hours resulting in the appearance of a bull s neck The edema also attains considerable proportions in the loosely attached tissues of the face and neck and may cause laryngeal and tracheal compression requiring tracheotomy

Redness of the nostril margin and the nasal vestibule and burning of the vibrissae of the nasal vestibule may signify a burn of the respiratory tract and lungs tracheotomy is indicated in burns with respiratory tract damage

Subsequent Care of the Burn Wound

The crust at first elevated above the intact skin gradually becomes depressed as a result of shrinkage due to drying The treatment of a dermal burn is terminated when the crust is desquamated The treatment of a full thickness skin burn ends after successful skin grafting Sequelae such as contractures and scars require late reconstructive procedures.

Superficial dermal burns are healed or nearly healed after approximately seven days. In deep dermal and mixed burn areas the thin slough which has formed may be removed carefully. A pearly white, growing epithelium or small granulating areas alternating with the islands of spreading epithelium are seen beneath the slough. The areas of deep burns appear as dark yellow brown or black sloughs separated from the surrounding tissue.

Removal of Sloughs

The spontaneous separation of burn sloughs is a process which may require weeks. Acceleration of this process has been attempted by the use of various enzymatic debriding agents such as trypsin and papain. None of these agents have been effective in our hands. Wet dressings are of assistance in removing exudate from the edges of the slough and if there is cellulitis in the tissue around the burn slough.

The most effective means of removing the burn slough is with scissors after the zone of liquified tissue has formed under the slough. The edge of the slough is picked up with forceps and the remaining strands of connective tissue still holding the slough are cut through with the scissors. After removal of the slough the area is treated with moist pressure dressings until the wound is filled with flat, bright red granulations which call for a skin graft (Fig 1111).

Skin Grafting

The preferred treatment of burns with full thickness loss of skin consists of covering the raw area by a dressing of skin thus minimizing contractures. A split thickness skin graft is employed to cover the raw area (Fig 1111). The graft may provide a repair of sufficiently good quality to be permanent (Fig 1112) but in some instances, especially in cases where the burned surface is extensive, as in Figure 1111 further reconstructive surgery is essential.

Cleansing and pressure immobilization transforms the unhealthy appearing surface which remains after the removal of the slough and produces a healthy bright red granulating area in a minimum period of time. Early grafting of the burn wound is usually successful; failures in skin grafting are often observed in older suppurating granulating areas.

Group A beta hemolytic streptococci have a particularly destructive effect upon skin grafts and upon viable epithelium in the superficial burn (Liedberg, Kuhn, Barnes, Reiss and Amspacher 1954). It is fortunate that these streptococci respond to penicillin administered either systemically or locally (Artz and Reiss 1957).

Many other types of streptococci, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Proteus vulgaris* and various enteric bacteria are also capable of colonizing the burn wound. Skin grafts are successful even in the presence of these microorganisms providing the inoculum is small.

Local antibiotic therapy is less effective than systemic administration (Hummel, Rivera and Artz, 1957). Systemic administration of antibiotics such as penicillin, tetracylin and bacitracin is required not only to control local wound infection but also to prevent local invasive infection or to treat bacteremia and septicemia, frequent complications of extensive burns.

Burns of the Auricle

When the auricular cartilage is exposed by destruction of the covering skin the cartilage becomes infected and softens and crumples leaving a deformed ear. Once initiated perichondritis may spread to the entire auricular cartilage. The only effective means of treatment of burns of the external ear with exposure of the cartilage is the excision of a sufficient amount of cartilage usually along the rim of the helix to allow adequate soft tissue coverage of the remaining cartilage. Wet dressings are effective in promoting drainage through suppurating fistulous tracts prior to sur

FIG. 1111

A. Full thickness burned face two weeks after child suffered burns in house fire.

B. *Skin graft dressing applied to the defect.*

C. Appearance of skin graft one week after operation.

D. Appearance of patient three months later. More severe deformity and contracture have been prevented; further reconstructive surgery is necessary.

(Courtesy of Dr. Charles C. Lund)

gery and antibiotics assist in avoiding spreading infection after surgery.

Electrical Burns

Accidents associated with the use of various mechanical and electrical devices are fairly common in the average modern home. Baldridge (1951) and Dale (1951), discussing the electrophysical aspects of electric burns, mention two general types, arc and contact. In the former, the involved area is heated by an electrical arc to a temperature of 2500 to 3000 C., resulting in a charring of the soft tissues and bone. In the latter, an electric current passes through the body from the point of contact to the point of grounded exit with burns at both sites; death may ensue if the current traverses vital cardiac or cerebral centers.

The burns in our series of cases are all of the arc type due to contact with live electrical sockets, the tissue injury being

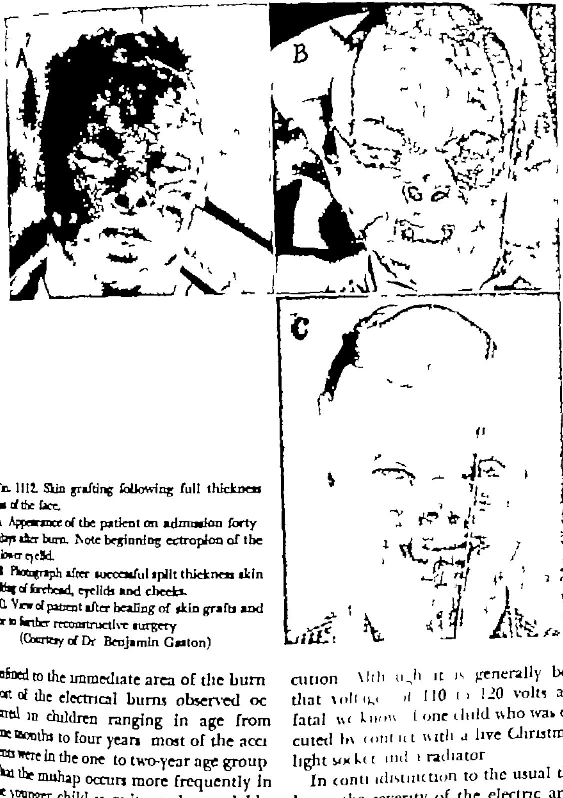

FIG. 1112. Skin grafting following full thickness burn of the face.

A. Appearance of the patient on admission forty-six days after burn. Note beginning ectropion of the left lower eyelid.

B. Photograph after successful split thickness skin grafting of forehead, eyelids and cheeks.

C. View of patient after healing of skin grafts and prior to further reconstructive surgery.

(Courtesy of Dr. Benjamin Gaston.)

confined to the immediate area of the burn. Most of the electrical burns observed occurred in children ranging in age from nine months to four years; most of the accidents were in the one- to two-year age group. That the mishap occurs more frequently in the younger child is quite understandable, for while creeping or playing, the live electrical cord left carelessly on the floor or the wall outlet becomes an object of curiosity which must be tasted. The moisture of the mouth completes the electrical circuit and the resulting arc burns the tissues. If the child is wet or is touching a ground object (i.e., a radiator) the current may pass through the body, even resulting in electrocution. Although it is generally believed that voltages of 110 to 120 volts are not fatal, we know of one child who was electrocuted by contact with a live Christmas tree light socket and a radiator.

In contradistinction to the usual thermal burn, the severity of the electric arc burn may not be apparent at first. Examination usually discloses a third degree burn with a centrally depressed charred crater and a slight, pale grayish elevation of the surrounding skin. Pathologic examination shows extensive coagulative necrosis extending a considerable distance beyond the apparent limits of the wound. The media of blood vessels is disintegrated; occasionally

FIG 1111

A Full thickness burned face two weeks after child suffered burns in house fire

B Skin graft dressing applied to the defect

C Appearance of skin graft one week after operation

D Appearance of patient three months later More severe deformity and contracture have been prevented further reconstructive surgery is necessary

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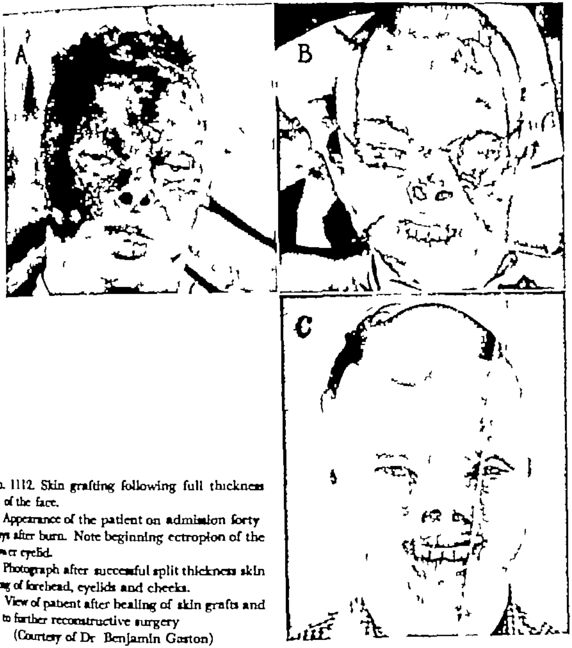

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C View of patient after healing of skin grafts and prior to further reconstructive surgery

(Courtesy of Dr Benjamin Gaston)

confined to the immediate area of the burn. Most of the electrical burns observed occurred in children ranging in age from nine months to four years most of the accidents were in the one to two-year age group That the mishap occurs more frequently in the younger child is quite understandable for while creeping or playing the live electrical cord left carelessly on the floor or the wall outlet becomes an object of curiosity which must be tasted The moisture of the mouth completes the electrical circuit and the resulting arc burns the tissues. If the child is wet or is touching a ground object (i.e a radiator) the current may pass through the body even resulting in electrocution Although it is generally believed that voltages of 110 to 120 volts are not fatal we know of one child who was electrocuted by contact with a live Christmas tree light socket and a radiator

In contradistinction to the usual thermal burn the severity of the electric arc burn may not be apparent at first. Examination usually discloses a third degree burn with a centrally depressed charred crater and a slight pale grayish elevation of the surrounding skin Pathologic examination shows extensive coagulative necrosis extending a considerable distance beyond the apparent limits of the wound. The media of blood vessels is disintegrated, occasionally

leading to secondary hemorrhage during the sloughing process. Sensory nerves are widely destroyed thus possibly accounting for the painless nature of the injury The devitalized tissues slough very slowly with a minimum of surrounding tissue reaction and tardy spontaneous repair Injured bone is slow to sequestrate.

Deformities Resulting from Electric Burns

The lips, alveolar processes and tongue are involved in live socket burns. Damage to the tongue is not usually severe although the tip of the tongue may show considerable ulceration in the initial stages Some impairment occurs when the floor of the mouth is involved the tongue being bound down by scars which interfere with normal motility of the tip

Burns of the alveolar processes and the teeth are common with resultant sequestration Loss of the deciduous incisors may occur but the development of the permanent teeth does not seem to be affected. The lip seems to suffer the most extensive damage the lower lip is usually more severely burned than the upper The entire thickness of the lip is usually involved including the mucosa of the inner surface and the alveolar process. The contracting scar causes severe deformities as the wound heals. When the median section of the lip is lost the remaining lip tissue becomes retracted and adherent to the alveolar process distorting the normal outline of the lips and interfering with normal function Part of both upper and lower lips of the injured side becomes adherent when the corner of the mouth is destroyed scar tissue interferes with the full opening of the mouth and results in considerable deformity (see Figs. 871 to 873 Chapter 23)

Treatment of Electrical Burns

The progressive necrosis which occurs in electrical injuries leads to a tendency to underestimate the severity of the lesions in the early stages. Wells (1929) held the view that early excision and grafting were the treatment of choice in the majority of cases. This has not been borne out by subsequent experience Early excision may be an advantage in selected cases in the early stages, however it is often impossible to judge the extent of damage caused by an electrical injury These lesions should be treated conservatively until the full extent of the damage has become apparent.

RADIATION BURNS

The discovery of the x ray in 1895 was followed closely by the sobering realization that this instrument of investigation and therapy could be a source of danger Reports of acute burns arising from its careless or indiscriminate use appeared in the literature within one year after its introduction Despite these early warnings, however ir radiation damage has continued to occur from the diagnostic and therapeutic use and misuse of the many sources of radiant energy which have been added over the years. The problem has been enormously complicated by the intentionally destructive utilization of radiant energy as an instrument of war the widespread ramifications of such usage fortunately still remain relatively unexplored on a clinical basis

Sources and Types of Radiant Energy

Roentgen s discovery was followed in 1896 by the Curies investigation of the properties of radium Radon subsequently evolved was followed in later years by the employment of high voltage x rays radioactive isotopes and concurrently the fission of the atoms of uranium and plutonium. Various types of radiant energy are derived from these sources those which are more pertinent to clinical effects of radiation on the skin follow

1 Alpha particles These are primarily

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responsible for cutaneous changes because of their low penetrating power They can be completely absorbed by an object as thin as a sheet of paper We are not concerned here with their extremely damaging effect if emitted from within tissues or if ingested or inhaled.

2 *Beta rays* These are more penetrating than alpha rays but markedly less than gamma particles they are filtered out by the interposition of thin clothing, lead or aluminum foil

3 *Gamma rays* These are considered to be hard rays similar to the x ray they have marked penetrating power and are capable of traversing the entire body with little diminution in their strength

Measurements and Units

The radiations referred to above are known as ionizing radiations, *i e.*, they have the properties of increasing the electrical conductivity of any gas through which they pass. This property recognized early in the history of the x-ray enabled the establishment of an international standard of dosage known as the Roentgen Unit or more simply "R. Other types of ionizing radiation are expressed in terms of the equivalent of so many Roentgen Units

Radiation Damage

There are qualitative and quantitative differences in the response of body tissues to radiant energy Shields Warren classifies cell reaction in the following order of decreasing radiosensitivity

- Lymphocytes and germ cells
- Granulocytes
- Epithelium
- Smooth Muscle
- Fibroblasts and derivatives
- Neurons

Epithelium is high on the list of sensitive structures alpha and beta rays are most damaging to it. The deeper penetrating x-rays and gamma rays are least damaging

Repeated small doses of irradiation over a long period are most likely to cause malignant changes radiant energy appears to have definite carcinogenic effect.

Deep x ray or radiation therapy in which the soft alpha and beta particles are screened out do not usually result in malignant skin changes

Exposure of the skin to radiant energy causes varying responses depending upon the intensity of exposure Erythema of a transient type usually occurs within twenty four hours of exposure and persists for approximately two days The erythema, accompanied by edema vesiculation and desquamation may reappear one to four weeks later The hair falls out in severe exposures and may be permanently lost. Ulceration occasionally develops early but is more frequently a late manifestation related to irritation or trauma The skin shows some brownish pigmentation following the acute phase and is generally smooth and shiny frequently dry often hairless and definitely atrophic. Telangiectasis is a late finding in radiodermatitis.

The radiosensitive epithelium shows variable cellular change, including atrophy dyskeratosis dysplasia loss of rete pegs hyperkeratosis and even complete destruction to the point of ulceration Eventual atrophy and destruction are sometimes due solely to an impairment of the blood supply which reflects damage to the underlying vessels The brown discoloration is due to an increase in the melanin content of the basal nerve cells.

The impoverished blood supply results from an obliterative endarteritis The response of the vessels to traumatizing irradiation consists of swelling of the vascular endothelium degeneration of the media and adventitia thrombosis fibrosis, and frequently perivascular edema and round cell infiltration The vascular impairment is associated with degeneration of the stromal elements with hyalinization of the collagen fibers and fragmentation of the elastic fibers The involved area unable to cope

with slight trauma and infection breaks down to form an indolent ulcer

Telangiectasia is due to the formation of relatively large vascular sinuses in the superficial layers of the corium. When thrombosis organization and perivascular hemorrhage develop in these sinuses they present an appearance described as "coal spots" by Brown McDowell and Fryer (1919) who believed that these areas act as foreign bodies or irritants producing exaggerated epithelial activity which eventually results in carcinomatous change from five to twenty five years after the exposure

Hair follicles, sebaceous glands and sweat glands show considerable variation in their response to irradiation damage the hair follicles and sebaceous glands being extremely sensitive and the sweat glands much more resistant Thus while epilation and dryness of the skin may accompany even mild states of radiodermatitis, the sweat glands function to some extent except in the more severe cases The changes in these appendages give the skin its characteristic smooth shiny quality

Malignant change has been demonstrated in 32.7 per cent of cases of radiodermatitis (Leddy 1936 Teloh, Mason and Wheelock 1950) found an incidence of 28.1 per cent in his series. The lesions are generally of a squamous cell type although some basal cell carcinomas have been reported and sarcomatous change has also been described Because of the effective barriers of thrombosed vessels and fibrotic change the lesion is usually localized although late spread can occur and the degree of malignancy is usually low

Treatment

Simpler lesions are treated by excision and closure either by the use of local flaps or skin grafts Destruction may be widespread requiring complete reconstruction of the nose ear or mandible It may be necessary to use skin from a distant source because of the impairment of adjacent skin employing tubed pedicled flaps or closed carried flaps. Damage may be so extensive that reconstructive procedures are difficult or impossible In such cases the affected area may be excised the raw surfaces covered with split thickness skin grafts, and suitable prostheses provided.

Carcinoma in Burn Scars

External chemicals were proposed as etiological factors in carcinoma after Percival Pott drew attention to the importance of coal soot as a stimulus to the onset of the condition Treves and Pack (1930) postulated that a scar from a burn was a poorly vascularized structure and was susceptible to ulceration because of poor nutrition, the inelasticity of the scar permitting the epithelium to be injured more easily than normal skin

Burn wounds that become carcinomatous usually heal only after prolonged periods of ulceration and are ulcerated again later in life for lengthy periods before the diagnosis of carcinoma is finally established

TREATMENT OF BURN DEFORMITIES

Reconstructive surgery of extensive burn deformities of the face is a difficult task because of the diffuse nature of the injury Early skin grafting prevents many of the marked deformities caused by burn contractures. The importance of early skin grafting cannot, therefore be over emphasized Contracture and surface scarring is increased when skin grafting of granulating burn wounds is neglected or delayed and the wounds are allowed to heal spontaneously or when skin grafting is unsuccessful

Repair follows the principles described elsewhere in the text for the treatment of facial deformities which result from skin loss and scar contracture The reconstructive treatment of burn deformities is described in chapters dealing with the various regions of the face (see Chapters 20 21 22 23 and 28)

Burn deformities of the face are of two


A B

Fig 1113 Burn contractures of the lower part of the face and neck

A. Contractures due to the spontaneous healing of deep burns. Note the pull of the scar tissue on the chin and the lower lip. Normal growth of the mandible was impaired in this child due to constriction by scar tissue.

B. The side view shows the obliteration of the anterior surface of the neck the chin is pulled toward the chest.

characteristic types (1) Contractures exerting traction upon the mobile structures of the face with deformity and functional disability and (2) Scars imprisoning the superficial musculature and abolishing facial expressive movements

1 Burn Contractures

Deformity is most severe in contractures resulting from skin loss not remedied by early grafting Restoration of the anatomic position of facial structures and of the symmetry of facial features is a prime requisite and a major achievement in restoring appearance and function Contracture of the skin of the neck may be so severe as to pin the skin down to the chest wall the cervical spine may actually be dislocated in rare instances (Fig 1113)

Contractures distorting the features of the face eyebrows, eyelids nose lips and cheeks and cervical area are linear consisting of a contractile band, or diffuse producing ectropion of the eyelid or lip or binding the chin to the chest in massive contracture following deep burns of the cervical skin

The Z plasty technique is an effective means of releasing linear contractures. When the contracture extends over a wide surface only replacement of the skin loss by grafts or flaps will correct the deformity

Skin loss at a distance from the area of contracture must also be remedied. An example is ectropion of the lower lip in burn

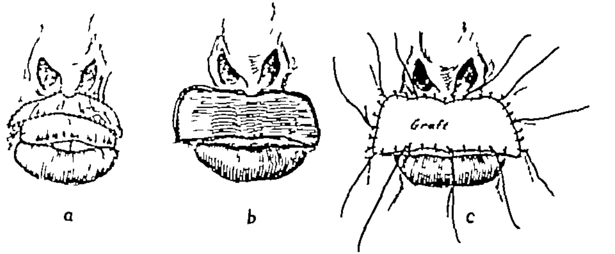


FIG 1114

A. Outline of scar tissue to be excised in order to release the scar contracture causing ectropion of the upper lip in patient shown in Figure 1116.

B. After resection of scar tissue the true defect is visualized The area delimited by the dotted line in Figure A represents the apparent defect.

C. The defect of the upper lip is covered by a full thickness graft. A number of sutures are left long and will be utilized to "tie-in" the pressure dressing

deformities involving the lower portion of the face and the neck It is not sufficient to correct the ectropion of the lower lip alone. The contracture of the cervical area due to skin loss should be corrected first by flaps or grafts recurrence of the downward pull of the lower lip will thus be prevented

Skin grafting is the method of choice for contractures of the forehead eyelids and lips (Fig 1114) Skin grafts are also indicated in contractures of the nose unless the re-establishment of the symmetry of the retracted alae results in a full thickness defect through the lateral wall of the nose which requires a pedicled flap repair preference being given to the forehead flap (Fig 1115)

Skin grafts may also be employed for the relief of contractures of the cheeks and neck under favorable conditions but in severe deformities pedicled flaps may be required (Figs 1116 1117 1118 and 1119)

2. Burn Scars

A disparity of color between the scar and surrounding tissue is rarely an indication for skin grafting since the color of the scarred tissue usually improves with the passage of tim replacement is indicated when keloidal scars are present. The extent and type of tissue replacement which will result in maximum esthetic improvement requires careful consideration a skin graft, which differs in color from that of the surrounding skin may be as unsatisfactory as the scar The possibility of covering the defect with a local flap often influences the decision to intervene surgically

In extensive burns of the face where the general color of the face is somewhat red, it is particularly important to avoid using a skin flap or graft which contrasts too greatly in color with the surrounding skin. Scarred forehead skin healed after superficial burns, may be employed to restore the covering of the external nose because its color is similar to that of the surrounding tissues (Fig 1115). Replacement of scar tissue by pedicled flap skin is required in thick scars (Fig 1120)

Many burn scars improve with time Massage and active use of the muscles of expression e.g grimacing forced opening and closing of the eyes, smiling or whistling help to re-establish facial muscle function.

Many patients, especially children are subject to hypertrophic scarring following burn injuries. After a lapse of time patients

A

B

C

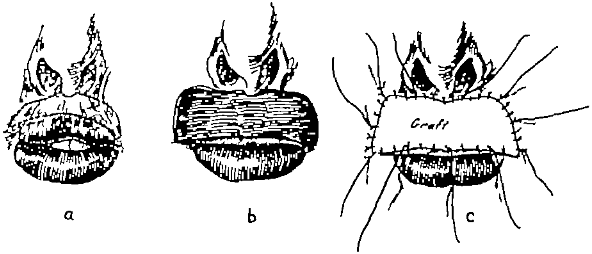
D

Fig 1115. Example of utilization of burned forehead skin for reconstruction of nose
A and B. Photographs of patient with marked alar retraction following gasoline burns.
C and D Result of nasal reconstruction by forehead flap.

seem to be less susceptible to hypertrophic scar formation and the scars become less conspicuous (see Fig 385 Chapter 16) Physiotherapeutic measures hasten the softening of the scars.

Repeated partial excision is employed when the surrounding tissue is loose healthy and elastic. In extensive surface scars of the side and lower part of the face flaps from the neck are generally used (Fig 1121) distant flaps may be required in rare cases A wide variety of flaps have been described and discussed in Chapter 23

When the underlying muscles of expression are imprisoned in deep layers of scar tissue the skin is shiny smooth and hairless and the face is an expressionless mask. The scar binds the lips until the mouth is tight, small and immobile. It may be necessary in such deep scarring, to replace the



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A B C D

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Fig 1116 Burn scars and contractures of the face

A. Appearance of fighter-pilot after spontaneous healing of deep burns due to the explosion of gasoline during combat. Note the contractures of the eyelids, nose and lips, the absence of eyebrows and the mask like appearance of the face caused by a thick layer of immobilizing scar tissue

B. Result obtained by reconstructive procedures shown in Figures 1117 and 1118 Further surgery to improve the scars and to thin the nose was prevented when the patient developed rheumatic fever

C. Profile view of patient shown in (A) Note the ectropion of the eyelids with forward displacement of the medial canthus, and the retraction of the ala and ectropion of the lips.

D Profile view of patient shown in (B) after reconstructive procedures.

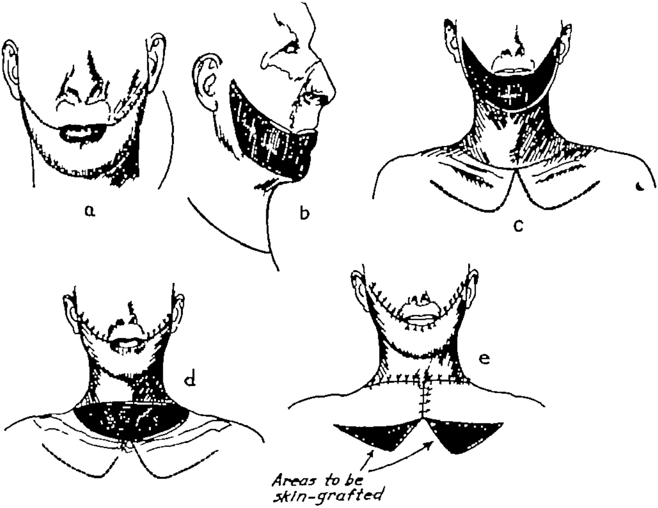


FIG 1117 Technique of bipedicled neck flap for reconstruction of the lower part of the face

A. Outline of area to be excised.

B. Illustrates the defect after excision of scar tissue.

C. Outline of circular incision at the base of the neck delimiting the pedicled cervical flap. Outline of secondary chest flaps is also shown.

D The neck flap has been transferred to the lower portion of the face.

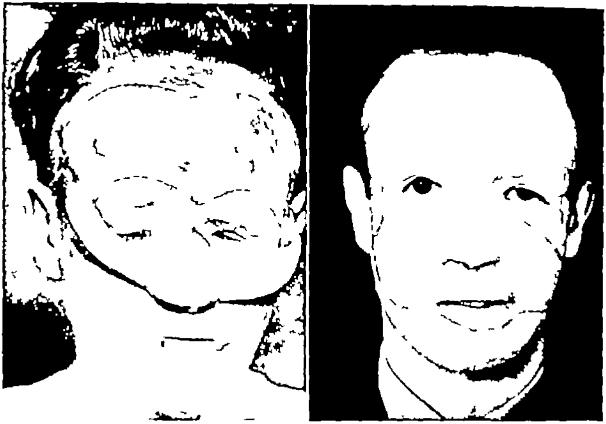
E. The secondary defect at the base of the neck is covered by two transposed chest flaps.

skin completely with skin flaps or grafts to liberate the facial muscles, but the restoration of facial expression is a difficult achievement. In burn scars without contracture partial thickness excision of the scarred area followed by split thickness grafting over the dermal bed is a method worthy of consideration (see Fig 458 Chapter 18)

When extensive burns involve the entire face the appearance of the skin after it heals, differs from that of the normal, and the introduction of normal skin by skin grafting or the transfer of pedicled flaps from a distance results in a patchy appearance of the face. It may be advisable to employ healed burned skin from an area such as the forehead to maintain a uniform appearance of the skin Healed burned skin following thermal burns or radiation therapy can be successfully transferred by the pedicled flap method.

Repair of Deformities due to Electric "Live" Socket Burns

Each case presents its own peculiar type of deformity although there appear to be two principal types of deformity (1) those which are limited to the corner of the mouth, and (2) those involving the loss of



A B

Fig 1118 Reconstruction of the middle portion of the face

A. Photograph taken ten days after the transfer of a bipedicled temporal flap comprising the skin of the entire forehead The forehead defect was covered by a single dermatome skin graft of intermediate thickness, demarcated by the dotted line. The median portion of the flap was placed over the nose.

B. In a second stage, two weeks later the tubed lateral portions of the flap were severed from the temporal area and utilized to cover the maxillozygomatic areas of the face. In a later stage eyebrows were restored

a section of the lower lip When the side of the mouth is involved the upper and lower lips are adherent for a varying distance from the corner of the mouth (see Fig 871 Chapter 23)

Reconstruction of the corner of the mouth becomes difficult when dense scar tissue is present. Two different procedures have yielded satisfactory results the choice depends upon the amount of missing mucosa at the vermilion border The adherent portions of the upper and lower lips are separated and the avascular scars are excised enabling the surrounding tissues to regain their normal elasticity the extent of healthy tissue required for repair then becomes more apparent. The skin loss seems to be negligible and mucous membrane only is required to re-establish the normal outline of the mouth If the raw areas at the corners of the upper and lower lips are not more than 1 to 1.5 mm in length an advancing flap from the adjacent vermilion lip can be used to restore this area (see Fig 872, Chapter 23) A horizontal incision is made at the mucocutaneous line and is extended medially from the wounds through the full thickness of the lip The incision should be of sufficient length to allow the vermilion flap to stretch to the new corner of the mouth it is anchored by a mattress suture which extends from the tip of the flap through the subcutaneous tissues of the cheek, and is brought out through the skin of the cheek at a distance from the corner of the mouth

FIG 1119 Reconstructive surgery for burn deformity of the face

A and B. Deformity resulting from burn caused by the ignition of a Halloween mask. Note the dense scarring throughout the face with contractures of the nose, lips and neck.

C. Shows the release of neck contractures after the transposition of a flap from the right clavicular and chest regions.

D Appearance of patient in the course of treatment.

E. Present appearance of patient.

More extensive loss of the vermilion portion of the lips cannot be repaired by the technique described above, but the vermilion portion of the lips can be replaced by mucous membrane flaps from the cheek (see Fig 873 Chapter 23) The wound resulting from the shifting of this flap is easily closed by suturing the elastic mucosa

Fig 1120. Pedicled flap repair in burn scars

A Dense scar tissue covers the left side of the face.

B. Tubed pedicled flap raised from the left brachial region and attached to the upper portion of the defect.

C. Tubed flap attached to the lower portion of the defect.

D Final appearance of the patient five years after covering the defect with the flap

Fig 1121 Corrective surgery for hypertrophic burn scars

A, B, and C. Scars resulting from burns incurred in the Cocoanut Grove disaster

D E and F Photographs illustrate procedures used to remove the scars. Rotation flaps from the neck were shifted in stages, gradually replacing the hypertrophic scar tissue. A full thickness retroauricular skin graft was applied to the bridge of the nose after excision of the scars. The cartilaginous bridge of the nose was trimmed in order to improve the contour

G Appearance of patient with make up at completion of treatment.

The new corner of the mouth is preserved by carrying some of the shifted tissue into the depths of the corner with a mattress suture brought out through the cheek as in the first method

When the median section of the lower lip and the mucous membrane of the lower alveolar process are lost, the lip becomes retracted and adherent to the buccal alveolar process normal mobility is restricted (see Fig 843 Chapter 25)

The initial procedure in reconstruction particularly in children is to release the lip from the alveolar process early in order to permit function even though some lip tissue is lost, for delay will interfere with normal growth of the lip Release of adhesions of the lip to the alveolar process is accomplished either by skin grafting or the transfer of uninjured mucous membrane from bordering regions When scarring is extensive skin grafting by the epithelial inlay technique is indicated after excision of the scar tissue. Skin grafts within the mouth, however tend to contract excessively normal mucous membrane from the bordering regions should be used when feasible A technique which has produced satisfactory results consists essentially of the V Y procedure. The adherent scars of the buccal sulcus are excised and a transverse incision made on each side of the wound in the buccal groove toward the molar region is extended vertically for a short distance as a relaxing incision. The two rectangular mucosal flaps thus created are brought together and sutured by the V Y method (see Fig 844 Chapter 25) Elasticity of the mucosa permits closure of fairly large-sized defects The raw area remaining on the alveolar process is covered by a split thickness skin graft at the same time, which also results in greater depth of the buccal sulcus. This procedure frees the lower lip from the alveolar process and increases its vertical dimensions, but does not increase the horizontal width of the lower lip

The loss of a section of the lip complicates further repair of the defect. Unless the lip loss is extensive however release of the lip from adhesions should be sufficient until the child has grown older

The replacement of missing skin and muscle should not be attempted until the child is older This can then be accomplished by borrowing a portion of the upper lip in the form of a reverse double Abbe Estlander or modified Stein operation (see Fig 858 Chapter 25)

30

PRINCIPLES OF MAXILLOFACIAL PROSTHETICS

The early history of maxillofacial prosthesis is difficult to trace but it may be assumed that the prosthetic restoration of missing parts of the face was practiced before surgical procedures became feasible According to Popp artificial ears noses and eyes were found in Egyptian mummies The Chinese also reconstructed missing parts of the nose and ears, using wax and resins of various types.

The prosthetic restoration of missing parts of the face and jaws as well as teeth were performed by surgeons who practiced dentistry Ambroise Paré was probably the first to use an obturator to close palatal perforations Pierre Fauchard in 1728 utilized perforations of palate to retain artificial dentures. Kingsley in a large volume (1880) described artificial appliances for the restoration of congenital as well as acquired defects of the palate nose and orbit. Claude Martin, in his book on prostheses (1889) describes very ingenious devices for the replacement of missing sections of the maxilla and mandible.

During the first World War artificial restorations were constructed in the main to serve as temporary supports for the soft tissues of the face when deprived of their skeletal framework such prostheses were indispensable for the rehabilitation of the patient Although surgical progress during the last 25 years has eliminated the need for some types of artificial appliances we feel that maxillofacial prosthesis continues to play an important role in restorative surgery of the face and jaws, employed in association with surgery

A prosthetic appliance on the face should have solid, non mobile margins not affected by the muscles of expression or mastication for mobility of the margins directs attention to the prosthesis It is thus often preferable to restore the mobile parts of the face by plastic procedures preliminary to the insertion of a rigid type of appliance Artificial restorations of the oral or nasal cavity must also rest upon a base of healthy tissue. For example when the soft tissues of the nose are to be supported by a prosthesis a cavity must be prepared and lined with a skin graft, previous to the insertion of the appliance

INDICATIONS FOR MAXILLOFACIAL PROSTHETICS

Although this text deals with trauma essentially and the repair of defects resulting from trauma the authors have also included cases of defects other than those due to injury in this chapter to emphasize the principles of prosthetic restoration

In traumatic deformities prosthetic restoration of missing parts of the face is indicated when surgical procedures cannot be expected to produce satisfactory functional or esthetic results For example when teeth are lost, prosthesis is the only method of

restoration Similarly when a section of the palate or alveolar ridge is destroyed, a prosthesis is preferable to surgery as a means of *restoration.*

A large defect of the skull can be corrected by transplantation of bone, but because of surgical difficulties a metal or plastic cover for the defect is sometimes indicated. Surgery is also inadvisable in certain cases because of the physical condition and economic status of the patient since a long period of hospitalization and a series of operations are frequently necessary

Prostheses have often been used as temporary expedients previous to or during surgical treatment, to maintain the tissues during the healing period. Use of such appliances hastens healing, prevents contraction and adhesions, and restores the contour of the affected parts. Immobilization of jaw fractures in which bone has been lost have been described in previous chapters intraoral appliances with attached molds are provided to support the soft tissues and to serve as a temporary framework for plastic operations on the lips and chin. The prosthesis, in such cases is discarded following transplantation of bone

ORBITAL RESTORATION

Ophthalmo-Prosthesis

When the ocular globe is destroyed or surgically removed it can be replaced by an artificial eye when other orbital contents and eyelids are present. Enucleation of the eye is commonly performed by ophthalmic surgeons the subsequent problem of fitting the patient with an ophthalmo-prosthesis *is distinctly within their province.*

Unusually Large Eye Sockets

In traumatic cases or defects resulting from disease the greater part of the orbital contents is often missing although the eyelids remain intact Surgery can reduce the size of the orbital space to accommodate an artificial eye The procedure consists of adding tissue either in the form of a dermal fascial cartilage or bone graft, or transposing tissue by means of a tubed pedicled flap. If surgery is not advisable an acrylic mold *can be fitted to the distal* part of a large orbit and an artificial eye inserted anterior to the mold. To obtain the desired shape of the acrylic prosthesis, softened dental compound is inserted into the socket, and the artificial eye is set into it in a position which harmonizes with the contour of the unaffected eye when the compound hardens, it is removed and duplicated in acrylic (Fig 1122)

During World War II Army and Navy dental surgeons (Murphy and Schlossberg *1944* Erpf S F., Dietz, V H and Wirtz, M 1945) dveloped artificial eyes of acrylic which proved more satisfactory than the eye constructed of glass the plastic eye is unbreakable and can be adapted to the socket with greater accuracy

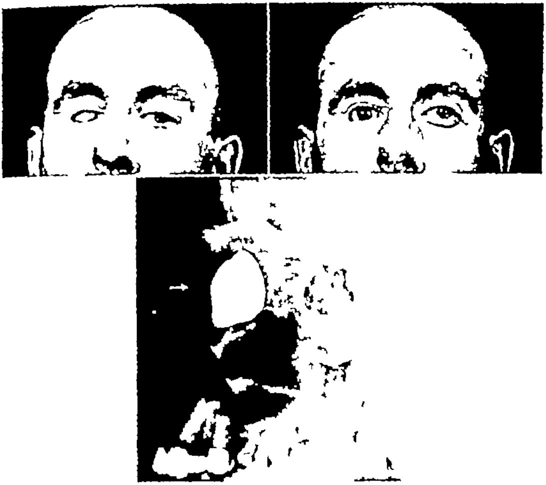
Construction of an Acrylic Orbit

Complete removal of the orbital contents and excision of the eyelids and surrounding tissue is sometimes necessary such a defect leaves a large exposed cavity (Figs. 1123*A* 1125*A*) and although a plastic operation may be considered, such a step is not always advisable. Total reconstruction of the eyelids by surgery has not proved satisfactory an esthetically modelled artificial restoration however is acceptable (Fig 1124*A* *C*).

The technique of constructing an orbital prosthesis consists of the following steps

1 A base plate of acrylic is fitted to the orbital cavity extending over the orbital rims This base is usually cone-shaped, and artificial eyelids are carved on it with modelling clay to harmonize with those of the unaffected eye, a task which requires the services of a sculptor The model is hollowed out to receive the eye and is then reproduced in acrylic. The artificial eye is inserted in the acrylic shell through an opening in the posterior surface and is then cemented into position The prosthesis is retained by its adaptation to the orbital

A B



C

Fig 1122

A. Photograph showing an unusually large eye socket following removal of orbital contents

B. Photograph of completed case with prosthesis in position

C. Roentgenogram showing an acrylic mold which was made to reduce the size of the socket and an artificial eye was fitted in front of the mold. The arrow points to the shadow of the artificial eye in front of the acrylic mold which is seen as a white mass behind the eye.

cavity and by attachment to a pair of spectacles. A groove on the nasal side of the prosthesis receives the heavy rims a bar is also extended from the external canthus to the arms of the spectacles. Heavy rimmed spectacles are preferable for they conceal the more conspicuous edges of the prosthesis (Figs. 1125 1126)

When tissue destruction is extensive involving the orbital contents, side of the nose, zygomatic region and a portion of the cheek (Fig 1127C) procedures similar to those described for the orbital restoration may be used with modifications in the outline and carving (Fig 1127*A* *B*) A disadvantage of such a prosthetic restoration is the exposed line of demarcation between the soft tissues and the prosthesis for this cannot be entirely concealed (Fig 1127*D*)

NASAL PROSTHESIS

Deformities of the nose caused by trauma are treated surgically and rarely warrant artificial restoration In the exceptional case the methods generally used in the construction of a prosthetic nose are best described under the following headings

1 Moldelling the nose
2 Materials used for reproduction
3 Methods of retention
4 Coloring and camouflage
5 Preliminary surgical procedures

A B

Fig 1125

A Loss of right orbital contents.
B. Prosthetic restoration of orbit.

Modelling the Artificial Nose

A plaster reproduction of the face serves as a working model the nose is modelled on the cast with clay or wax. A knowledge of sculpturing is essential in this procedure for shaping a nose to harmonize with the facial contour and individual type is an artistic achievement. For these reasons the services of a sculptor are usually indicated.

Materials used for Reproduction

Materials such as porcelain celluloid copper silver aluminum gelatin compositions, vulcanite and latex have been used in the past in the construction of the prosthetic nose A number of these have been discarded in favor of the acrylics. The authors have always preferred the rigid type of artificial nose rather than those made of soft acrylic or latex Flexible types depend on glue for retention and latex is not durable. Patients have also complained that they are unable to use handkerchiefs or control nasal secretions

Hard acrylics are advantageous for several reasons they are translucent and easily processed into the desired shape modification of the shape is also possible after the work is completed. Furthermore color may be incorporated in the material so that the artificial nose matches the color of the face

Methods of Retention

A rigid type of prosthetic nose may be retained by spectacles, by contact adhesion with the nasal and facial tissues, by extensions into the nasal cavities and by various devices extending from the oral cavity to the nose Figure 1128 illustrates a typical prosthesis, utilizing all available methods of retention The inner surface of the prosthesis (A) fits over the boundaries of the nasal opening and covers an area consistent with the shape of the nose Prolongations of the restoration rest upon the floor of the nose to prevent it from slipping down onto the lip (B) Lateral grooves (C) and also a metal clasp over the artificial bridge (D) fit the bridge and rim of the spectacles accurately An even pressure is thus exerted

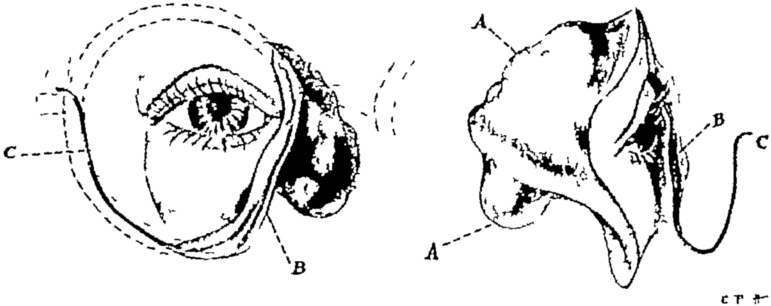


Fig 1124 Restoration of orbit following loss of orbital contents Orbital prosthesis consisting of a vulcanite base covering the entire orbital cavity Over this base artificial eyelids were molded and an artificial eye in serted to match the normal eye. Retention was acquired by extending the base material to cover the entire orbital cavity (A) a groove was made along the nasal side of the prosthesis to fit the frame of the spectacles (B) in addition a spring wire extended from the lower end of the groove behind the lower rim of the spectacles to the hinge of the bow (C)

(From V H Karanjian, J Dent. Res. 12.651 1932)

A B

FIG 1125

A. Photograph of patient with loss of orbital contents and eyelids.

B. Photograph of completed case

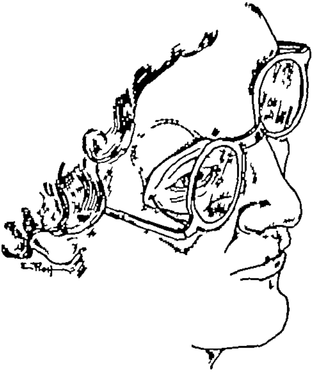
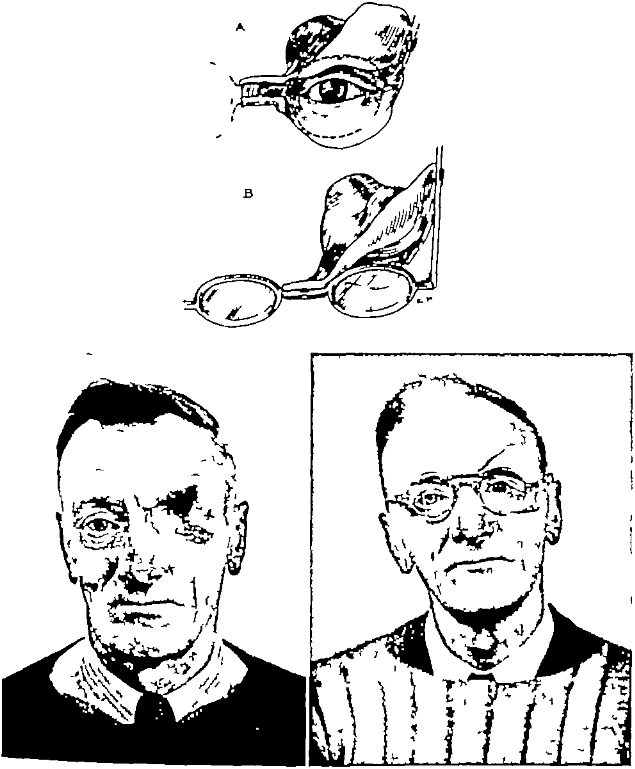


FIG 1126. Diagram of orbital prosthesis which is held in position by (1) accurate fit to the orbital cavity and (2) by spectacles the frame of which fit into a groove on the nasal side, while a bar extends from the side of the spectacle frame to the outer border of the prosthesis, thus holding the prosthesis close to the orbital rim.

by the spectacles on the upper half of the nose when the prosthesis is in place

Successful retention of such a prosthesis is essential for the comfort of the patient and for the general appearance Slight dislodgment invariably disturbs the fit of the appliance and spaces between the prosthesis and the nose become conspicuous. All available means of anchorage must be utilized in each case the undersurface of the appliance must fit the tissues accurately and be in contact with the available tissue under its base to achieve stability

The use of spectacles is one of the oldest and most common methods of retention the spectacles being fastened to the bridge of the nose in order that the entire weight of the appliance is supported by the auricles through the lateral arms of the spectacles. This method however has mechanical weakness unless other means of support are included The spectacles cannot be secured sufficiently to achieve the desired degree of retention when the spectacles are attached to the bridge of the nose the pres-



C D

FIG 1127

A and B Artificial acrylic orbit, tinted with celluloid paints and carrying an artificial eye, is retained in position by accurate adaptation and eyeglasses. In such cases, the artificial orbit is more conspicuous because the line of demarcation cannot be entirely concealed by the spectacle frames.

C. Photograph of patient who had lost the left orbital contents, involving the supraorbital ridge, temporal bone and zygoma.

D Restoration of orbit with prosthesis.

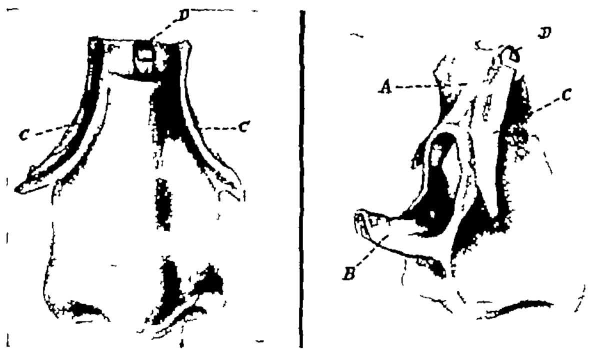


FIG 1128 Drawings of a nasal prosthesis. Main features of prosthesis (1) inner surface (A) base fitted accurately and covered as much space as consistent to shape of nose (2) prolongations of restoration (B) rested upon the floor of nose, purpose being to prevent artificial nose from sliding down upon lip (3) lateral grooves as well as mental clasp over bridge (C and D) fitted accurately to bridge and rims of spectacles, so that when nose is worn, there is even pressure from spectacles to upper half against tissues of face.
(From V H Kazanjian, J Dent. Res., 12.651 1932)

sure on that area tends to dislodge the lower border The pressure is therefore focused at the lateral aspects of the middle of the prosthesis to remedy the condition (see Fig 1128C) using glasses with heavy frames. The lower curvature on each rim and also the bridge is thus fitted accurately the greatest amount of pressure being exerted at the lowest point The glasses are not fixed to the prosthesis the two appliances being maintained in their correct relationship when the spectacles are adjusted

Spectacles although accurately adjusted will not prevent the prosthetic nose from sliding downward To prevent this annoying feature *extensions of the appliance* into the nasal cavity are necessary An appliance that does not fit accurately and does not cover a considerable area is not tolerated by the delicate nasal mucosa the floor of the nasal fossa is therefore the *most practical location for the extensions* (Fig 1128*B*) Figure 1129 illustrates a nasal prosthesis similar to that shown in Figure 1128 When ever possible, a nasal prosthesis should be anchored to an artificial denture because the combined prosthetic restoration results in a greater degree of stability Figure 1130 shows a case of extensive destruction of the nose, lip and palate in which both surgical and prosthetic means were employed A nasal prosthesis was anchored to an artificial denture each portion of this combined restoration supported the other the *reciprocal anchorage thus affording maximum stability* This case is an excellent illustration of the possibilities of prostheses in mutilated cases and also indicates the use of surgery to improve the upper lip which should remain mobile (Fig 1131) A palatal or buccal perforation between the nasal and oral cavities (see Fig 1130) offers a suitable means of attachment for the artificial nose (see Fig 1133) If necessary such a perforation can be made sufficiently large at the inner aspect of the upper lip to permit the passage of an extension from the buccal

FIG 1129 Photographs before and after insertion of a nasal prosthesis similar to that illustrated in Figure 1128. This appliance was worn by the patient for over twenty five years.

plate of the denture such a case is illustrated in Figure 1135

Preliminary Surgical Procedures

A preliminary surgical porcedure is often necessary to lessen the prominent demarcation lines excision of a section of the lower end of the septum may also be required to stabilize the appliance The prosthesis is less conspicuous if it does not extend to the mobile parts of the face, and if the lines of demarcation are hidden by spectacles by the natural folds of the face, or the fold of the ala and base of the nose. Surgical procedures are undertaken to reduce the size of the perforation into the nasal cavity to conform to these boundaries (Fig 1132) Figures 1130 to 1134 exemplify the judicious employment of surgery and prosthesis resulting in the rehabilitation of a major deformity of the nose, lip and palate An artificial restoration which includes the nose and upper lip may satisfy esthetic requirements but is not a practical solution since the lip must be mobile in order to achieve proper function. As a preliminary step therefore the upper lip should be reconstructed surgically

Prostheses have been employed to form a skeleton for the bridge of the nose when the nasal soft tissues are intact this method is of use only in selected cases. The most suitable are those in which the anterior part of the palate and cartilaginous support of the nose are missing It has been found practical to make an extension to the maxillary side of a denture to support the tip of the nose (Fig 1136)

MAXILLARY PROSTHESES

Defects of the palate varying in size from small perforations to complete loss of the hard palate, may be closed successfully by means of prosthetic appliances Missing alveolar processes and teeth may be restored artificially the appliance when indicated may be extended into the nasal cavity to support the soft tissues of the nose

Preliminary surgical measures simplify the problems attending prosthetic design The chief problem lies in finding a means of re-

FIG 1130. Photographs showing extensive destruction of the nose, lip and palate (Figs. 1130 to 1134 from V H Kazanjian Plast & Reconstruct. Surg., 2 307 1947)

tention for the appliance Remaining teeth and remnants of the hard palate and alveolar process are generally depended upon for anchorage and provide a base for stability during mastication When a portion of the maxilla is missing and an insufficient number of teeth remain however it is necessary to find other support such as that available in the nasal fossa

Temporary Dentures

Patients with large defects of the maxilla are usually referred to the prosthodontist long after the original operation or initial injury Contraction of soft tissues may therefore offer an additional obstacle to the successful construction of the prosthesis. We have long advocated the use of dentures, prepared preoperatively to serve as temporary supports. Such a denture can be constructed soon after the operation the patient s denture can be modified for such a purpose or a base plate may be constructed even though the wound is as yet unhealed (Fig 1137) Figure 1138A shows a case of extensive injury of the face and maxilla In

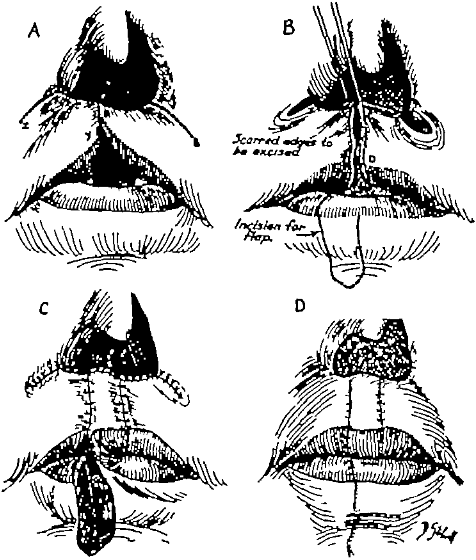


FIG. 1131 Diagrams of the various stages in the Estlander-Abbe operation, for the reconstruction of the upper lip

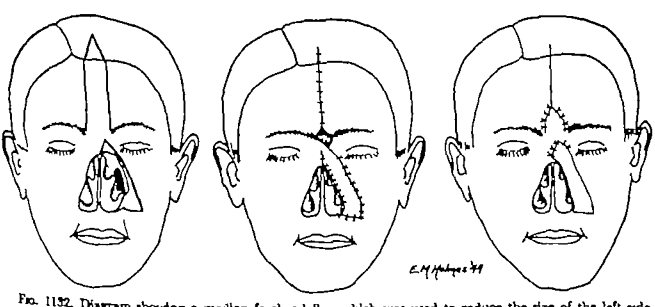


FIG. 1132. Diagram showing a median forehead flap which was used to reduce the size of the left side of the nasal opening.

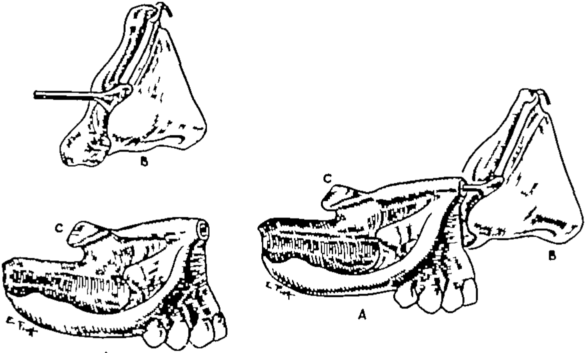


FIG 1133 Diagram of nasopalatine prosthesis. Part (A) shows the denture which fits over the remaining part of the edentulous palate. Retention is obtained by an extension (C) over the floor of the nose posteriorly and by a nasal bar and tube attachment which locks the artificial nose (B) to the denture quite securely

A

B

C

D

FIG 1134

A Photographs showing the repair of the upper lip by the Estlander Abbe procedure in patient shown in Figure 1130.

B Shows the anterior end of the horizontal tube attached to the upper surface of the denture The bar extending from the nose fits into this tube

C and D Photographs showing the artificial nose in position. Retention is obtained by the bar and tube attachment to the upper denture and also by the spectacles

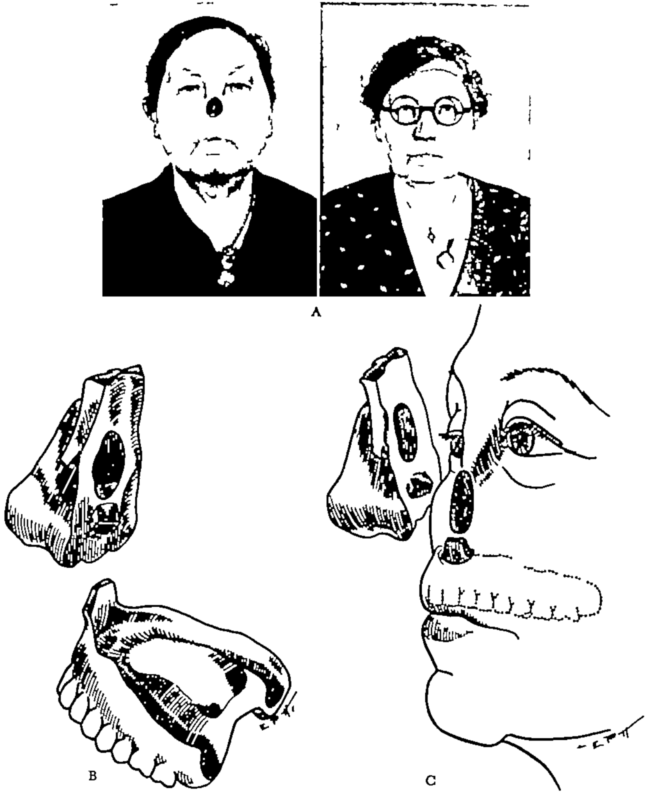


Fig 1135

A. Photographs of patient with loss of the lower two-thirds of the nose restored by a nasal prosthesis re
ained by spectacles and by an attachment to the upper denture.

B. Illustrations of the denture and nasal prosthesis shown in A and C.

C. Under local anesthesia an incision was made in front of the nasal spine into the mouth and the bor
lers of mucosa were sutured to the skin. The upper denture was supplied with an upper extension which
assed through the buccal perforation. The artificial nose carried a groove into which the projection of the
pper denture fitted.

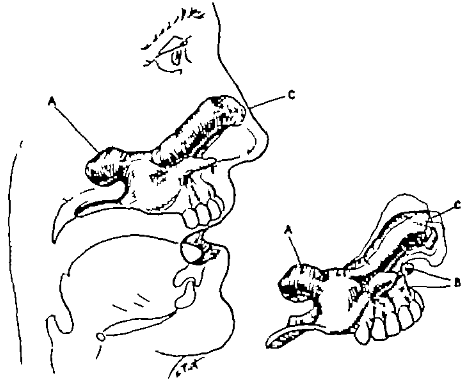


FIG 1136. Diagram showing a maxillary prosthesis in a case with loss of the anterior two-thirds of the maxilla. The denture is retained in position by an extension posteriorly over the floor of the nose, behind the perforation (A) and anteriorly where the projection rests upon the floor of the nostrils. The large extension (C) offers intranasal support and corrects the nasal depression.

A B

FIG 1137

A. Drawing of plaster cast showing a large perforation of the hard palate following surgery

B. Base-plate to cover the palatal defect, constructed soon after operation.

which a temporary denture served to immobilize the parts during surgical procedures. Such a temporary denture can be modified to serve as a permanent restoration at a later date.

Use of a temporary denture which covers the defects adds to the patient's comfort, for difficulty experienced in speech and in eating is lessened and secondary contractions and adhesions of the soft tissues are mini

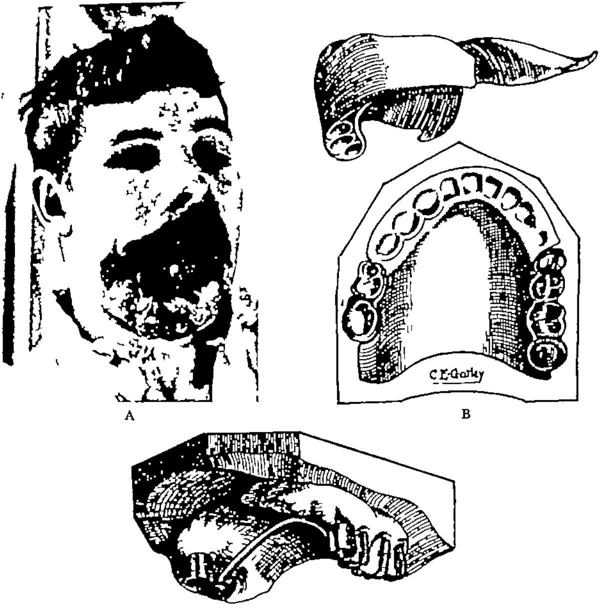


Fig 1138

A. Photograph showing extensive destruction and partial loss of the anterior portion of the maxilla due to injury

B. Plaster cast of the maxilla and dentition of the patient seen in (A) showing the destruction of the maxilla anteriorly and a fracture of the right molar region, and a dental splint to immobilize the fracture.

C. The temporary base plate is retained by attachment to the wire of the splint, and has sufficient fullness and contour to prevent undesirable adhesions and contraction of the soft tissues. This temporary appliance served to immobilize the parts. After surgery the appliance was modified (see final result in this patient in Fig 810)

mized. The temporary denture however does not always prevent secondary contraction if the raw area is extensive. In such cases, skin grafting is resorted to either immediately following the operation or at a later period.

Methods of Retention

Loss of part of the maxilla, coupled with loss of teeth, obviously creates an obstacle to stabilization The remaining alveolar ridges, the palate and the teeth should be utilized to retain artificial restorations, extending the denture through palatal spaces into the nasal cavity and employing various spring attachments which extend from the lower jaw to the upper denture.

1 The advantages of utilizing the maximum amount of the available portion of the palate and alveolar ridge surface are to re

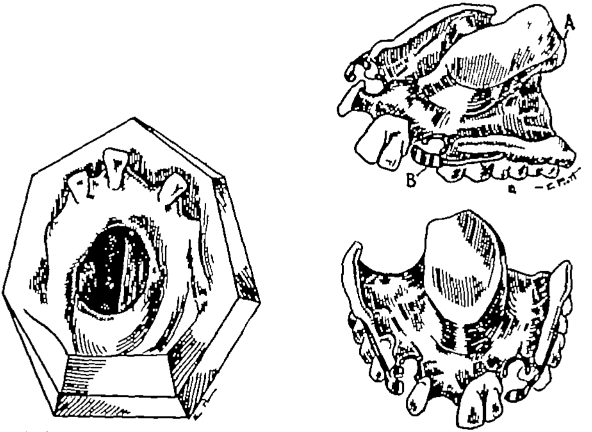


FIG 1139 Diagram showing large perforation of the hard palate and three anterior teeth in divergent positions and appliance used to cover perforation. Note extension of denture over nasal surface (A) and resilient type clasp (B) used over divergent anterior teeth.
(From V H Kazanjian, J Oral Surg., 5 181 1947)

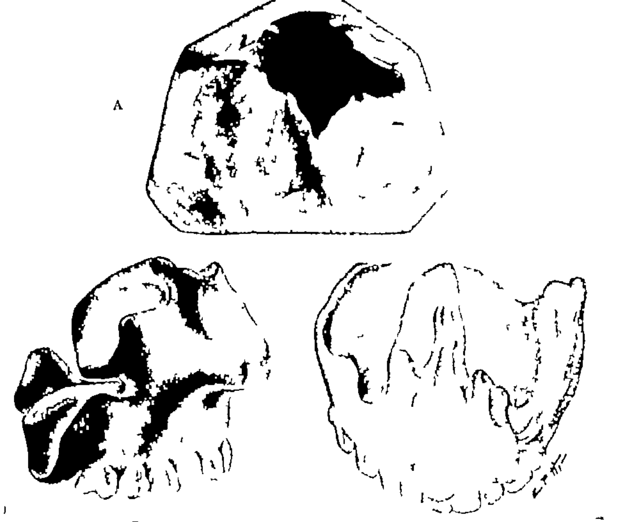
tain the denture, afford stability and in crease masticating efficiency Because the teeth are the most dependable means for an chorage it is important to retain them when ever possible employing light resilient clasps

2 Spaces leading to the nasal cavity are next in importance for retention this prin ciple if used wisely has a wide range of application It is desirable, however to survey the entire area and make the projections of the denture harmonize with the laws of leverage and with the existing conditions of the soft tissues. Projections of the denture may be extended above the posterior border of the palate into the nasopharyngeal space (Fig 1139) laterally into the cavity of the maxillary sinus utilizing the anterior wall and into the floor of the nose toward the base of the anterior nares (Fig 1140) In some cases a hinged projection facilitates introduction of the movable portion to the nasal side (Fig 1141) A denture may also be constructed in two sections, introduced separately into the oral cavity and locked together with clasps after insertion (Fig 1142)

It is at times necessary to reoperate in order to establish a favorable space for the successful retention of a denture In such cases, it is advisable to remove adhesions of the mucosa and apply a skin graft within the oral cavity or nasal fossa thus establishing a membranous lining for a denture

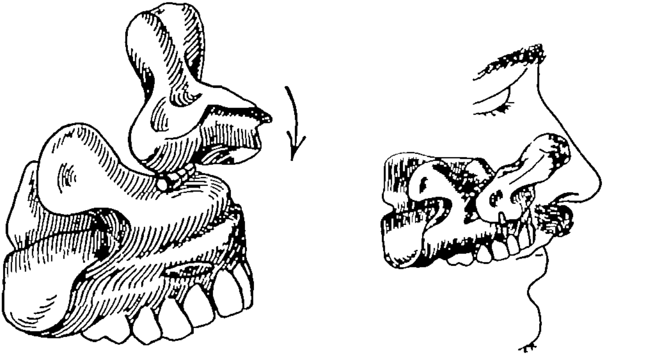
3 Spiral springs illustrating another means of denture retention have been em ployed successfully in the past the principles remain useful

The oldest and most generally used spiral spring is made of special gold wire about 0 5 cm in diameter and 5 cm long It is at tached by means of suitable buttons on each side of the upper and lower dentures, at or



A B C

Fig. 1140 (A) Cast of edentulous maxilla with the anterior thi[...] the palate missing Retention of the denture is accomplished by a projection toward the nasopharynx post[...] and the lips anteriorly (B and C)

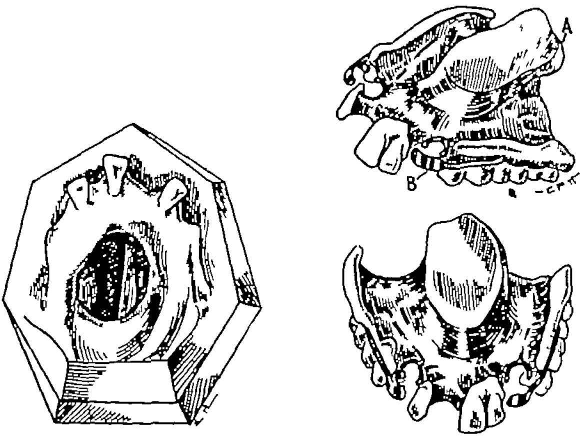


A B

Fig 1141

A. Diagram of a denture designed for a patient who suffered extensive loss of the maxilla, resulting in a large perforation into the nasal cavity Retention is obtained by projections of the denture anteriorly and posteriorly The anterior part is hinged to facilitate introduction of the denture.

B. The anterior hinged projection, in addition to holding the denture also supports the lower part of the nose.



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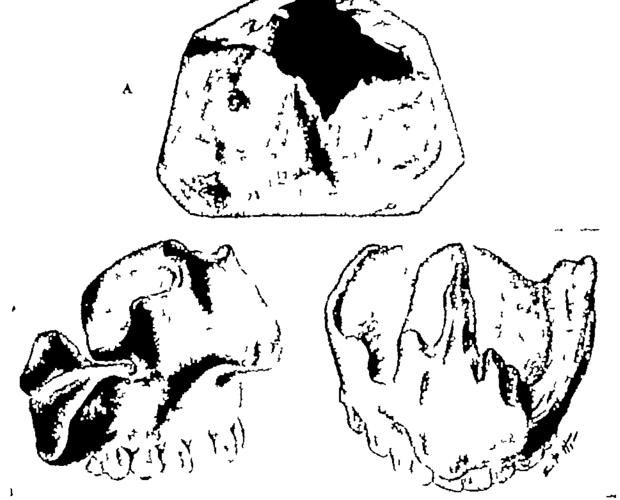
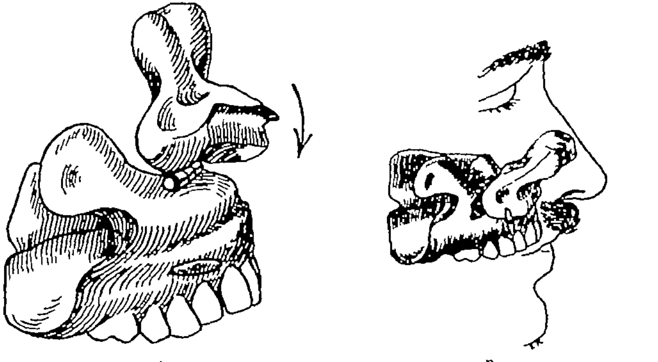


Fig 1140. (A) Cast of edentulous maxilla with the anterior third of the palate missing Retention of the denture is accomplished by a projection toward the nasopharynx posteriorly and the lips anteriorly (B and C)



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B. The anterior hinged projection, in addition to holding the denture, also supports the lower part of the nose

A B

C D

Fig 1142. Large defect of the palate and alveolar ridges

A, B and C. A permanent appliance was made in two sections (B) introduced into the oral cavity independently and locked together after insertion (C) Retention was gained by projections from the maxillary side of the prosthesis, one anteriorly toward the nostrils and the other posteriorly into the nasopharyngeal space.

D Photograph showing appliance in position. It may be of interest to add that such an appliance is still functioning satisfactorily after many years of service

(From V H. Kazanjian, The Apollonian, 12 242, 1937)

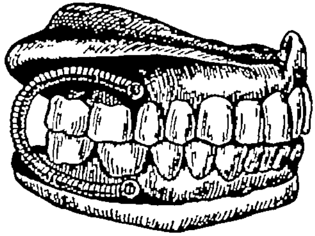


Fig 1143 Illustrating the use of spiral springs for denture retention. The spiral spring is attached in the bicuspid region by means of hinged buttons. The spring rests upon the groove made on the buccal side of the denture

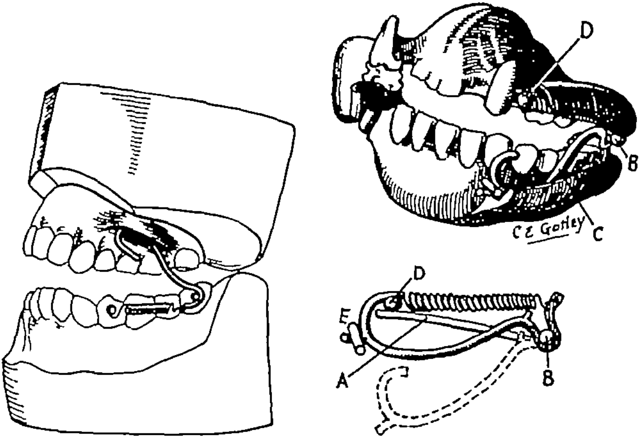


Fig 1144 Illustrating another means of employing the principles of the spring

(*Left*) The spring is attached to an anterior button at one end and to the short arm of a lever at the other end in the post molar region. The posterior button acts as a fulcrum for leverage.

(*Right*) The spring and lever attachments which can be reversed to permit the lever to slide in a groove on the buccal aspect of lower denture When this method is used, it is necessary to include a catch (E) to act as a bite guide.

about the first bicuspid region These springs rest upon grooves on the buccal side of the dentures the spring assumes a semicircular position (Fig 1143) when the teeth are in contact.

The second type, originally devised in 1913 consists of a horizontal spring connected with a lever Two buttons are attached to the lower plate or bridge one at the bicuspid region and the other at the third molar region (Fig 1144) A horizontal spring is attached to the anterior button at one end and to the short arm of a lever at the other the posterior button acts as a fulcrum to the lever The long arm of the lever fits into a groove made on the buccal aspect of the upper plate. The tension of the spring retains the denture as the patient opens and closes the mouth.

Spring devices employed for denture retention have some disadvantages They do not serve a useful purpose unless they are accurately constructed and their strength is measured carefully They require frequent repair are not easy to keep clean and at best afford a limited degree of stability for the dentures. For these reasons their use is limited to those cases in which other means have failed

4 Deformities involving loss of part of the palate and nose orbit, or side of the face may be effectively repaired by connecting the facial prosthesis with an upper denture if an extraoral prosthesis is indicated (Fig 1145) Such appliances are constructed in two sections one covering the upper jaw and the other covering the facial defect. They are fastened together by suitable attachments passed through the communicating areas.

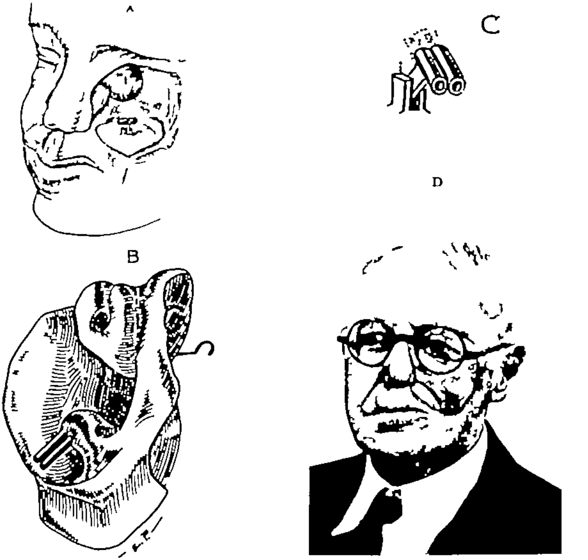


FIG 1145 Orbito-facial prosthesis

A. Drawings showing loss of the left eye entire left maxilla and part of the left cheek.

B and C. The prosthesis was constructed in two sections and the upper surface of the denture supplied with two parallel tubes to hold the facial prosthesis. The facial restoration (B) includes metal rods which pass into the tubes. The frames of the spectacles offer additional support

D Photograph showing prosthesis in position. The prosthesis was constructed by Dr L. K. Daghlian at the Harvard School of Dental Medicine. The material employed, acrylic resin, was painted with celluloid paints to match the color of the surrounding skin.

(Figs. 1145 to 1147 from V H Kazanjian J Oral Surg 5 181 1947)

Figure 1146*A* illustrates a perforation of the right side of the palate Because teeth were present on the right side a denture was made and retained with clasps. The right side of the denture extended into the perforation to act as a seal and a three point contact for retention was achieved (Fig 1146*B* C) with an extension of the denture over the nasal surface of the perforation.

A device employed to close an excessive nasopharyngeal defect is shown in Figure 1147 An appliance such as this must be under complete control of the palatopharyngeal musculature in order that its movements may harmonize with those of the soft palate The posterior border of the palatal base bears a hinged joint to which a movable obturator is attached for a rigid appliance

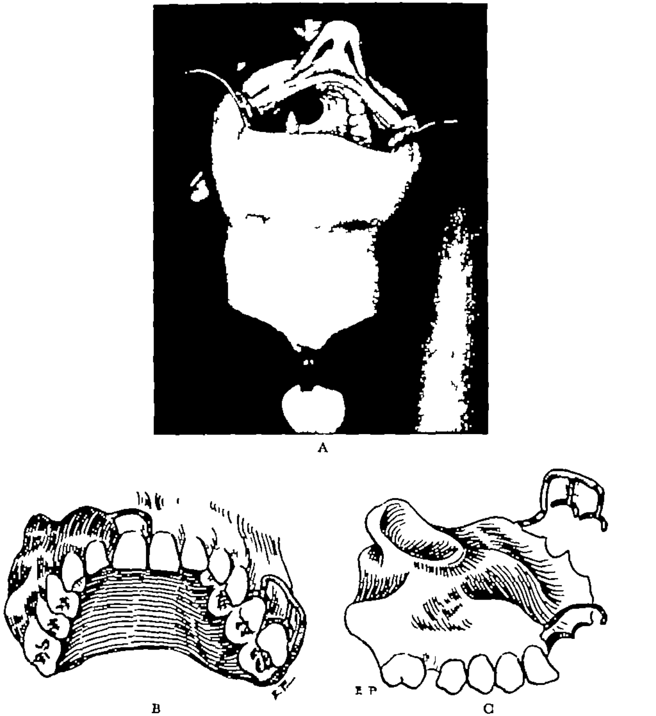


Fig 1146

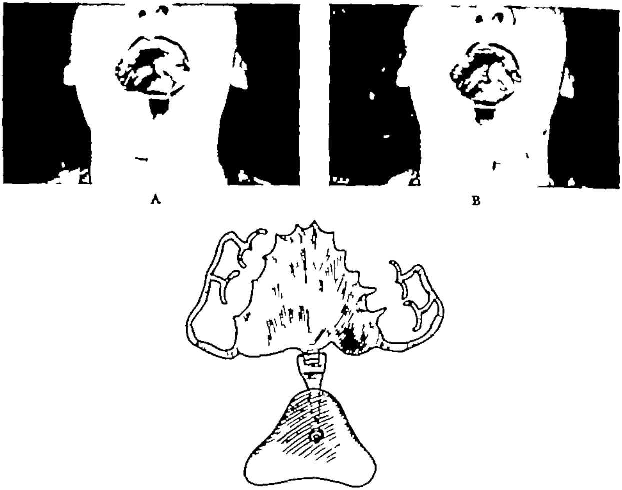
A. Photograph showing a perforation of a portion of the palate.

B and C. Diagrams of a denture, retained in position by clasps in the left molar region and over the central incisors. Retention was accomplished also by an extension of the denture over the nasal surface of the nasal perforation, thus affording three point contact for retention

in patients with this type of defect is not as satisfactory

The appliance made for the patient shown in Figure 1147 consisted of a metal base plate with a hinged obturator (Fig 1147*C*) The anterior and lateral borders of the obturator fitted and slightly overlapped the nasopharyngeal surface of the soft palate and the contour of the posterior border harmonized with the movements of the pharyngeal musculature.

The successful construction of an appliance for a patient with a short velum is more difficult than for a patient with a cleft



C

Fig 1147

A. Photograph showing nasopharyngeal defect.
B. Photograph showing obturator in the oral cavity
C. Drawing of the obturator

of the soft palate the appliance must be under complete control of the pharyngeal muscles.

AUXILIARY MEANS FOR INCREASING THE MASTICATORY EFFICIENCY OF AN ARTIFICAL DENTURE

Partial loss of the maxilla even when more than half of the upper jaw is destroyed may still afford sufficient support for a device which is capable of resisting the forces of mastication Total or almost complete loss of the maxilla is the result of severe injury This type of condition offers no such means of resistance The oral and intranasal tissues even though healthy are not capable of withstanding the forces exerted by the elevator muscles of the jaw

Campbell (1918) and others have succeeded in transplanting bone and soft tissue in a series of operations to close large defects of the maxilla in order that a simpler type of denture may be employed The authors depend on prosthetic appliances to supply a cover for large losses of maxillary bone

The necessary areas of resistance however have been obtained by means of an appliance which transfers the force to more distant structures, namely the anterior surface of the frontal bone and the supraorbital ridges. A denture is made which replaces the destroyed maxilla and two horizontal tubes parallel to the occlusal plane are embedded in the denture with their open ends high in the canine region Ascending wires which

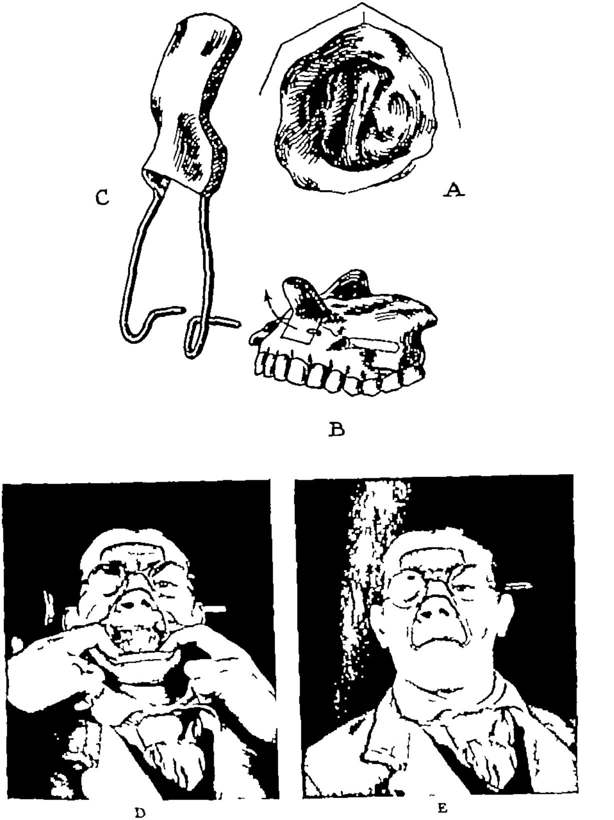


Fig 1148

A. Drawing of a plaster cast of a case with loss of the entire maxilla, resulting in a large perforation surrounded by a ring of soft, cicatricial mucosa.

B. The denture is retained in position by anterior and posterior extensions into the nasal spaces. The anterior projection is hinged to facilitate its introduction into the nasal cavity

C. Extraoral appliance consisting of a saddle to fit over the frontal eminence and infraorbital ridges.

D and E. The extraoral appliance is shown in position. It is used only when the patient is masticating

fit these tubes emerge from the corners of the mouth pass upward on either side of the nose and terminate in a resistant base, adapted to the frontal eminence and supra orbital regions. The base or saddle is retained in position by a pair of firm spectacles, equipped with a tape or elastic cord which passes from their bows around the occipital region. The bony prominences of the supraorbital region lend themselves to this procedure for they lie parallel to the occlusal plane of the maxilla. The extraoral parts of the appliance wires, saddle spectacles, and tape need only be used when the patient is masticating (Fig 1148) We have had occasion to use this appliance in three such cases, with gratifying results. The first of these was constructed as far back as the year 1911 The extraoral appliance appears much less conspicuous if transparent acrylic and stainless steel wire are used.

It has been repeatedly emphasized in the preceding chapters that the contour of the soft tissues of the lower part of the face is dependent on the underlying framework. When this framework is lost it can be replaced by transplanted bone plus an artificial denture. It has also been emphasized that when massive destruction of the maxilla and mandible occurs, the remaining parts should be preserved and retained in their normal anatomical positions by various devices outlined in the foregoing chapters. Future reconstruction is aided by such procedures.

MANDIBULAR PROSTHESES

Mandibular deformities requiring special prosthetic reconstruction may be classified into two general groups.

Group I

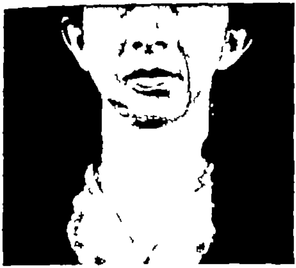
Deformities of the mandible which fall into this grouping are characterized by considerable loss of bone and teeth but the continuity of the mandible remains intact These deformities result in a loss of the normal contour of the lower third of the face and an inability to masticate

The primary aim of treatment is to prepare the oral structures for the successful retention of a denture of sufficient bulk to improve the contour of the face Surgical preparation consists of freely undermining the buccal and labial mucosa deepening the buccal sulcus, and applying a skin graft A lower prosthesis is inserted immediately following this step to fit the newly created alveolar ridge (Fig 1149)

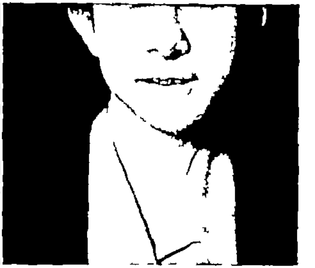
Deformities caused by malunited fractures are also included in this group. Repair of such deformities is usually achieved by surgical methods. Borderline cases, however may be encountered in which one may hesitate to subject the patient to osteoplastic repair a prosthetic appliance can be constructed for such a condition preparing the mouth for its reception by less drastic surgical procedures Figure 1150 illustrates this type of case in which the patient suffered a compound, comminuted fracture of the lower jaw and the fragments had been permitted to consolidate without considering the occlusion of the teeth As a result the remaining lower teeth including one molar on one side and three teeth on the other side slanted lingually and were completely out of contact with the upper teeth. An osteoplastic procedure would have involved cutting through the median section of the mandible, immobilizing the fragments to restore good occlusion and at a later date transplanting bone to fill the gap in the mandible Less drastic measures were employed The buccal and lingual aspect of the alveolar ridge was freely undermined and a skin graft applied The space thus formed in the oral cavity and the existing teeth were used for retention of a lower prosthesis. This procedure improved the contour of the face and permitted the use of an efficient denture

Group II

The second group of mandibular deformities are those in which an entire section of the mandible is missing It should be emphasized that defects of the mandible even



A



B

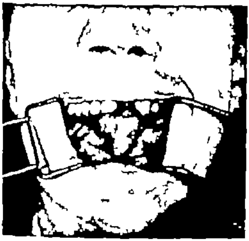
C

FIG 1149

A. Photograph of patient whose teeth and greater portion of the body of the mandible were lost, the continuity of the mandibular border remaining intact.

B. Photograph following insertion of the large lower restoration shown in (C)

C. Drawings of the appliance used by the patient (see A)



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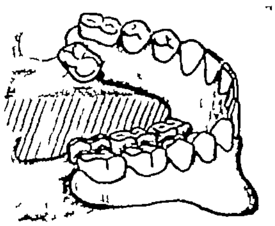


B

FIG 1150

A. Photograph showing marked contraction of the alveolar arch, with the remaining posterior teeth on both sides completely out of contact with the teeth of the maxilla.

B. Drawing of the large, lower prosthesis constructed for the improvement of the condition shown in (A) The outer flange of this appliance fits into a surgically prepared sulcus in the oral vestibule and the artificial teeth are arranged outside of the natural molars, occluding with the teeth of the upper jaw restoring masticatory efficiency

Fig 1151

A. Photograph of patient with extensive loss of the mandible.

B. Photograph indicating by dotted outline on neck, the area of skin used as a delayed flap the skin of this region being hairless. The dissected flap was reflected upward, forming a sulcus in the oral cavity for the retention of the prosthesis shown in (C)

D Photograph of patient, with large restoration in position.

though extensive can be repaired by transplantation of bone In this chapter however the possibilities of prosthetic devices are outlined in the event that surgery is contraindicated

In cases such as these in which mandibular function is limited, the degree of function that can be restored is dependent upon the size and anatomical position of the existing bone and upon the presence or absence of teeth These cases differ the condition depending on the degree of lateral and backward displacement thus resulting in disturbance of occlusion and normal functioning of the jaw

In favorable cases the correction of the deformity may be achieved by mechanical manipulation and orthodontic appliances in others the presence of cicatricial tissue demands surgical intervention

Loss of the Median Section of the Edentulous or Semi-edentulous Mandible

It is difficult to secure the retention of a denture in an edentulous patient a degree of stability may be attained however by

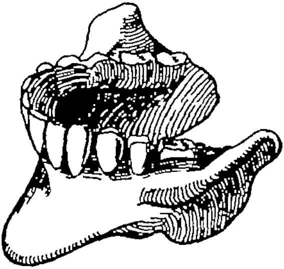
the formation of a deep pocket lined with epithelial tissue. The pocket is formed to correspond with the missing bone and the raw area of the pocket is lined with a skin graft or a delayed flap from the lower part of the neck. Figures 1151 and 1152 are typical examples.

Loss of a Lateral Section of the Mandible

Destruction of bone in this group may be limited to the mandibular condyle and part of the ramus or may extend to the body of the mandible and be sufficiently extensive to involve the median section and a portion of the opposite side leaving only a small

A

C



B

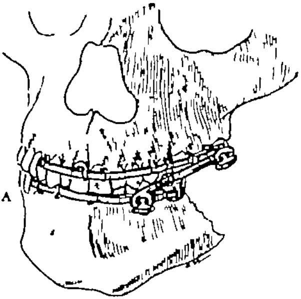
Fig 1152

A. Photograph showing loss of the entire body of the mandible.

B. Prosthesis designed for restoration of the jaw and face following the use of a number of temporary splints which served to retain the soft tissues in position.

C. Photograph following insertion of large prosthesis shown in (B)

A



B

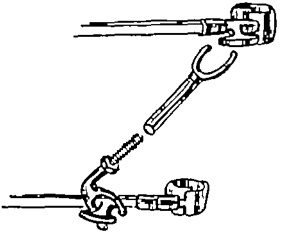


FIG 1153

A Temporary bite guide applied early to prevent the mandible from sliding backward when the posterior fragment is missing The appliance consists of two banded arch wires with buttons soldered to the buccal sides of the bands. The arch wires are adjusted to the upper and lower teeth. A bar forked at both ends, extends from the upper last molar to the lower cuspid region When the teeth are in contact the bar forces the lower jaw into normal position.

B. The bar is made in two pieces consisting of a tube and a threaded wire The threaded nut regulates the length of the bar

segment to act as a base for artificial restoration

The number of teeth in the remaining part of the mandible is an important factor since the prosthesis is designed primarily to utilize these teeth for purposes of retention and also to assume the burden of mastication

Obviously there is a great functional loss in such cases, depending upon the extent of loss of bone and teeth partial function however may be developed by the use of properly constructed prostheses

The loss of a part of the ramus may not necessarily interfere with function of the mandible if the remaining portion of the mandible is free of trismus and distortion from adherent scars. Adhesions and scars require surgical treatment following surgery an appliance is made employing the

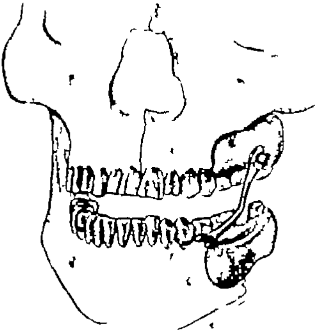


FIG. 1154 The mandibular bone defect extended from the left bicuspid region posteriorly When the upper posterior teeth are missing, as in this case, the patient is supplied with two partial dentures. A hinged bar extends from the last molar region of the upper denture to the bicuspid region of the lower jaw When the patient occludes the teeth the intermaxillary hinged bar forces the lower jaw into normal position.
(From V H Kazanjian Am. J Surg 43 249 1939)

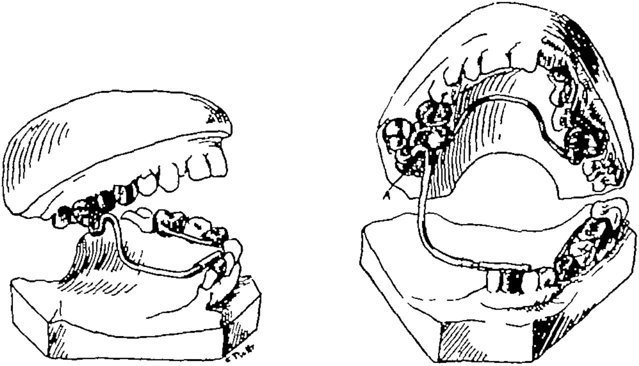


FIG 1155 A retention appliance is shown, in a case where the right half of the mandible is missing The mandibular teeth are covered a tube is welded to the lingual surface of the incisors. A bar inserted into the lingual tube, below fits into a prepared socket in the splint attached to the teeth of the maxilla the socket is located in the last maxillary molar region.
(J W McNichols, *Prosthetic Dentistry* C. V Mosby Co. 1930)

principle of the simple inclined plane or occlusal guide to attain correct occlusal relationships.

When destruction of one side of the mandible includes the ramus and part of the body on the same side, the articulation of the remaining teeth is disturbed by a lateral and backward swing of the mandible The primary object of a prosthesis in this type of case is to retain the mandible in normal position to maintain proper occlusion of the remaining teeth.

Various types of prosthetic appliances are used successfully in such cases. A practical type is a retention appliance constructed to correct the facial contour and to facilitate functioning of the remaining mandibular segment. Such an appliance may extend from the last tooth of the anterior segment on the side of the defect backward and upward toward the maxillary third molars, where a pseudo-temporomandibular joint is established in the form of either a groove or a ball and-socket joint (Fig 1153 1154 and 1155) The purpose of these appliances is to prevent the backward and inward swing of the remaining segment of the mandible.

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